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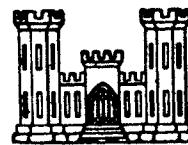
**CORPS OF ENGINEERS, U. S. ARMY**

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**PLANS FOR ELIMINATION OF SHOALING  
IN  
THE VICINITY OF HEAD OF PASSES, MISSISSIPPI RIVER**

**HYDRAULIC MODEL INVESTIGATION**



**TECHNICAL MEMORANDUM NO. 2-356**

**WATERWAYS EXPERIMENT STATION  
VICKSBURG, MISSISSIPPI**

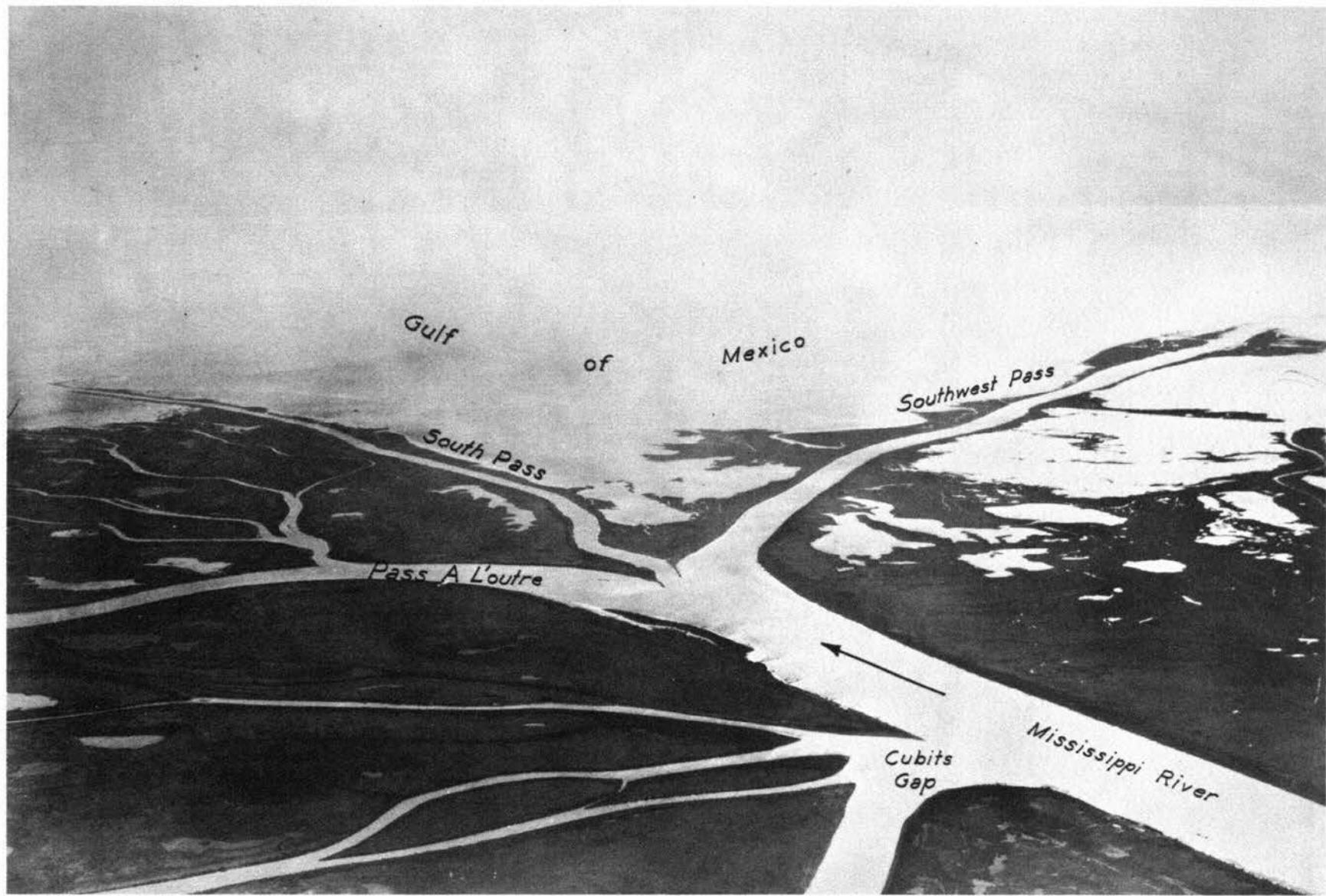
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**FEBRUARY 1953**

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FRONTISPICE. Head of Passes

## PREFACE

The Head of Passes model study was initiated by the District Engineer, New Orleans District, New Orleans, Louisiana, and was authorized by the Chief of Engineers in the 2nd indorsement, dated 31 July 1939, to a letter from the District Engineer dated 13 July 1939. The study was conducted by the Hydraulics Division of the Waterways Experiment Station during the period August 1939 to September 1942. During the course of the investigation, close liaison was maintained between the New Orleans District and the Experiment Station, chiefly through semi-monthly progress reports, special reports, and inspection trips. Complete analyses of the various phases of the study were submitted to the District Engineer upon completion of the model tests involved. Prior to and during the study Experiment Station personnel visited the prototype problem area. Military and technical assistants to the District Engineer also visited the Experiment Station during the adjustment and operation of the model.

Frequent conferences were held with Mr. R. M. McCrone of the Mississippi River Commission and Messrs. W. C. Cobb and J. S. Gentilich of the New Orleans District, who observed much of the testing program and devised certain of the tentative improvement plans tested. Personnel of the Waterways Experiment Station actively connected with the study were Messrs. J. B. Tiffany, J. M. Caldwell, G. B. Fenwick, J. J. Franco, W. H. Robertson, A. M. Gill, W. A. Moore, C. E. Lee, and L. J. Morgan.

## CONTENTS

	<u>Page</u>
FRONTISPIECE: Head of Passes	
PREFACE . . . . .	i
SUMMARY . . . . .	v
PART I: INTRODUCTION . . . . .	1
The Problem and Its Locale . . . . .	1
Existing (1939) Projects . . . . .	3
History of the Problem Area . . . . .	3
Purpose of the Model Study . . . . .	5
PART II: THE MODEL . . . . .	7
Area Reproduced . . . . .	7
Type of Construction . . . . .	7
Scale Ratios . . . . .	9
Appurtenances . . . . .	9
PART III: DISCHARGE-DISTRIBUTION TESTS . . . . .	11
Test Procedure . . . . .	11
Results . . . . .	12
PART IV: VERIFICATION OF THE MODEL . . . . .	14
Principle of Model Verification . . . . .	14
Procedure . . . . .	15
Results . . . . .	16
PART V: TESTS OF PROPOSED IMPROVEMENT PLANS . . . . .	18
Test Procedure . . . . .	18
Base Test (Test 2) . . . . .	20
Plans A, B, and C . . . . .	22
Plans D, E, F, G, and N . . . . .	26
Plans H, I, J, K, L, M, and T . . . . .	32
Plans P, O, and Q . . . . .	41
Plans R, R-1, R-2, R-3, and S . . . . .	45
Plans U, V, W, and V-1 . . . . .	50
PART VI: DISCUSSION OF RESULTS . . . . .	56
Interpretation of Model Results . . . . .	56

## CONTENTS (Continued)

	<u>Page</u>
PART VI: DISCUSSION OF RESULTS (Continued)	
Summary of Results . . . . .	57
TABLES 1-8	
PHOTOCGRAPHS 1-6	
PLATES 1-33	
APPENDIX: ADDITIONAL TESTING PROGRAM	
TABLES A1-A3	
PHOTOCGRAPHS A1-A6	
PLATES A1-A14	

## SUMMARY

The Head of Passes model study was conducted for the purpose of determining the most economical and effective plan for the elimination or reduction of shoaling in the Mississippi River near the Head of Passes.

A movable-bed-type model, constructed to linear-scale ratios of 1:500 horizontally and 1:150 vertically, reproduced seven miles of the Mississippi River above the Head of Passes, all of South and Southwest Passes, the upper two miles of Pas a Loutre, and the upper one-half mile of Cubits Gap. Cubits Gap and Pas a Loutre were each controlled to discharge a fixed proportion of the flow, while the discharges in South and Southwest Passes were controlled by maintaining the water-surface elevation at their lower ends to mean Gulf level.

The testing program was divided into three phases: (a) discharge-distribution tests; (b) verification of the model; and (c) tests of proposed improvement plans. The discharge-distribution tests consisted of preliminary tests to determine the effects of various proposed improvement works upon distribution of discharge among the passes. Tests were also conducted to determine the effects of contraction works constructed in Southwest Pass and of the dredge cut (then in progress) in that pass from mile 10.5 to the Gulf upon the discharge distribution. Verification tests were conducted after the model had been adjusted to establish hydraulic operating conditions. These tests reproduced accurately the changes in bed configuration which occurred in the prototype during the period between the 1937 and 1939 prototype surveys. The tests of improvement plans consisted of a base test and tests of 27 plans tentatively

proposed for the improvement of the channel in the vicinity of Head of Passes.

Results of the discharge-distribution tests demonstrated that the over-all hydraulic resistance of any pass is the controlling factor in determining the discharge in the pass, and that none of the proposed works for the improvement of channel conditions produced any very appreciable change in the discharge distribution among the three passes. These tests also indicated that the progressive decrease in the percentile discharge carried by Southwest Pass, as observed in the prototype between 1937 and 1940, was produced by regulating works (spur dikes) constructed in the pass during that period. It was also found that about two-thirds of this decrease in discharge would be restored by the dredge cut then being constructed in Southwest Pass from mile 10.5 to the Gulf.

Tests of the proposed improvement plans indicated that the plan recommended at that time by the Board of Officers\* would not effect the desired channel improvements in the Head of Passes area. Only two of the other improvement plans tested appeared to offer solutions. One plan, R-1, produced in the head of Southwest Pass a 35-ft channel approximately 900 ft wide having within it a 40-ft channel 800 ft wide. The other plan, plan V, produced in the head of Southwest Pass a 35-ft channel 900 ft wide having within it a 40-ft channel 600 ft wide.

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\* See paragraph 11 of main text.

PLANS FOR ELIMINATION OF SHOALING IN THE VICINITY OF

HEAD OF PASSES, MISSISSIPPI RIVER

Model Investigation

PART I: INTRODUCTION

The Problem and Its Locale

1. The Head of Passes of the Mississippi River is located approximately 95 miles below New Orleans, Louisiana, and is the upper end of the three principal outlets to the Gulf of Mexico. Reference to the frontispiece and figure 1 will serve to establish the geographical location of the problem area.

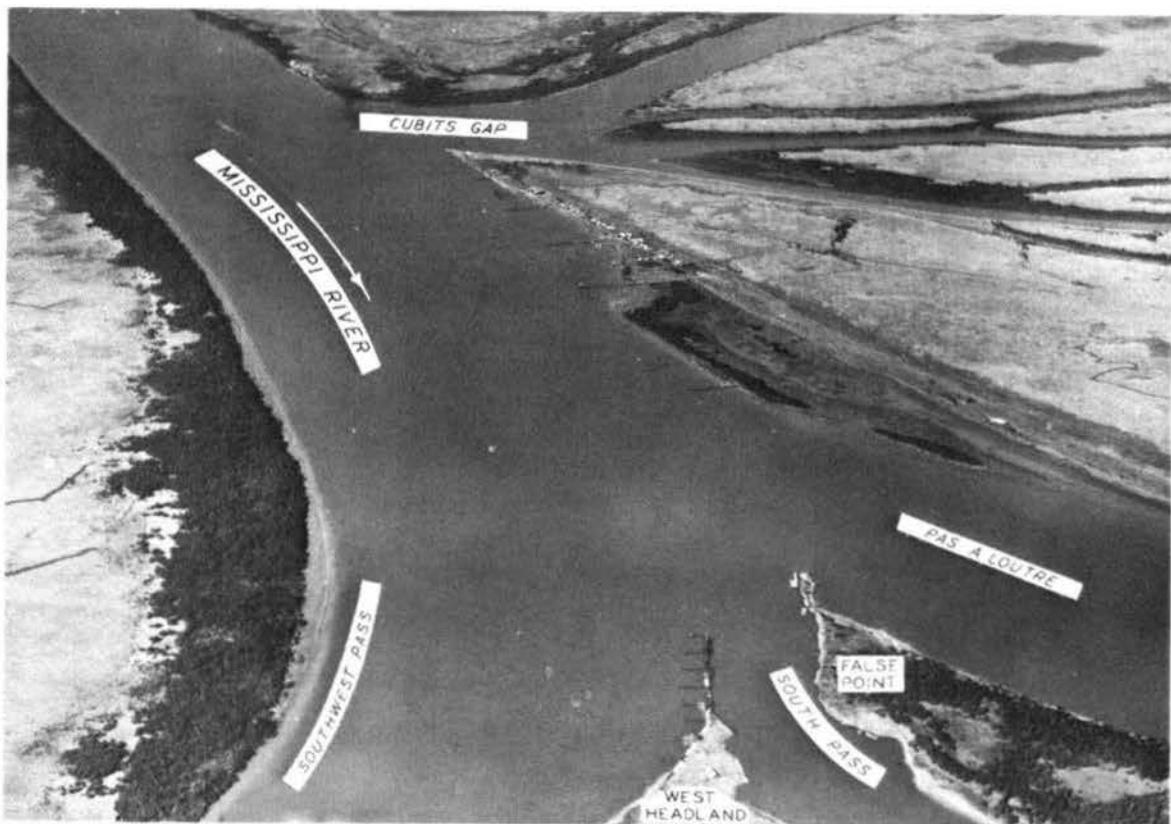


Fig. 1. Aerial view of the Head of Passes reach looking upstream

2. The Mississippi River flows into the Gulf of Mexico through several natural outlets, of which Pas a Loutre, South, and Southwest Passes are the most important. Pas a Loutre is the largest and carries the greatest proportion of the total flow, but only South and Southwest Passes have been developed to accommodate deep-water navigation. South Pass, the shorter of these two, offers a satisfactory, self-maintained navigation channel 26 ft in depth. The greatest difficulties of navigation by this route are found at the head and foot of the pass during high water. Ships have some difficulty in making the turn into the pass because of the limited width at the foot of the pass, the velocity of emergence, and the westerly set of the current leaving the pass. An unfavorable channel alignment exists at the head of the pass because of the relative positions of the West Headland dike and False Point on the opposite (east) side of the pass; a strong eddy which at times is hazardous to navigation exists just below False Point.

3. Considerable shoaling difficulty has been experienced in Southwest Pass, particularly at its head and below mile 10. Above Cubits Gap, which is considered the upper limit of the Head of Passes area, minimum depths of 65 ft below mG1 exist, while immediately below the Gap the river begins to shoal until at the head of Southwest Pass annual dredging is necessary to maintain project depths. From just below the head to about mile 10, Southwest Pass increases in width and decreases in depth, and a considerable amount of annual maintenance dredging has been required on the outer bar and in the lower channel. The problem with which the model study was principally concerned was the elimination or reduction of shoaling in the head of Southwest Pass.

Existing (1939) Projects

4. In 1939 the existing project provided for a channel through Southwest Pass 1,000 ft wide and 35 ft deep. The project provided that the details of the work might be modified at the discretion of the Secretary of War. The principal features of the general plan of improvement in effect at that time in Southwest Pass were a dredged channel on the outer bar inclined  $36^{\circ}00'$  to the left of the jetty axis, the contraction of the lower 2 miles of the pass to 1420 ft, the contraction of the next ascending 4.5 miles to 1750 ft, and a dredged entrance channel at the head of Southwest Pass.

5. For South Pass, the existing project in 1939 provided for a channel 26 ft in depth, not less than 200 ft wide at the bottom, and having through it a central depth of 30 ft without regard to width. The principal features of the general plan of improvement in effect at that time were a uniform channel section, self-maintained from head to foot, and a dredged channel through the outer bar, inclined  $37^{\circ}30'$  to the left of jetty axis.

6. A recommended revised project provided for a 40-ft channel between the Gulf of Mexico and the port of New Orleans via Southwest Pass. Although this revised project was not officially approved, some of the proposed plans studied in the model were designed with a view toward obtaining a channel of 40-ft depth through Southwest Pass.

History of the Problem Area

7. One of the major problems at the passes has been the maintenance

of proper balance of flow through the three main passes. For many years during the development of the passes, submerged sills were placed across the heads of the various passes in efforts to adjust the discharges through the three main passes. However, various submerged sills were constructed and removed without affecting the discharge distribution, as the natural resistances of the over-all channels themselves were the controlling influence affecting the discharge.

8. The sill across the head of Southwest Pass was removed in an effort to increase the discharge in that pass. A sill was placed across the head of South Pass in 1917 and was extended 800 ft upstream in an unsuccessful effort to check the increase in discharge. A large scour hole, more than 100 ft in depth, developed below the South Pass sill and became a threat to the stability of the headland structure between South Pass and Southwest Pass. In an attempt to eliminate this hole, a center section of the sill about 420 ft wide was removed in 1935 with no noticeable effects on either the discharge or the scour hole.

9. Spur dikes were constructed in 1918 along the left bank of the main river below Pilottown in order to train the flow of the main river more toward Southwest Pass. A slight increase in the discharge of Southwest Pass was claimed to have resulted from these works. The left-bank dikes were extended and additional dikes constructed upstream in 1923, reducing the width of the main river from 4600 to 4000 ft; this latter construction was claimed to have produced a slight increase in the flow of Southwest Pass at the expense of Pas a Loutre. The dikes were again extended in 1935-36 and additional dikes constructed farther

upstream; however, no material change in flow distribution resulted from the latter construction.

10. West Headland dike was constructed in 1923-24 between the head of South and Southwest Passes in an attempt to increase the discharge of Southwest Pass at the expense of South Pass. However, the flow through South Pass continued to increase at the expense of Pas a Loutre while that of Southwest Pass remained about stationary. Eight spur dikes were constructed along the Southwest Pass side of the West Headland structure in order to contract the entrance to Southwest Pass and, at the same time, to protect the headland structure. The contraction offered by the construction of the spur dikes was not sufficient to improve the entrance channel. The entrance channel at the head of Southwest Pass is presently maintained by annual dredging.

#### Purpose of the Model Study

11. The initial purpose of the Head of Passes model study was to determine the effectiveness of the improvement works for the Head of Passes area recommended in the interim report of the Board of Officers\*, dated 10 June 1938, to the Chief of Engineers, subject: "Interim report of the Board of Officers appointed to determine what work may be advisable to complete the existing project for Southwest Pass, Mississippi River, . . . . ." It was believed advisable, in view of the importance and complexity of the Head of Passes area, to obtain all possible information as to the probable effects of the proposed works in that area

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\* Board of Officers appointed by paragraph 2, Special Orders No. 21, Office, Chief of Engineers, dated 7 March 1938.

before undertaking actual construction. This conclusion led to the request for the model study. The model study therefore resolved itself into the determination of the following specific information: (a) the effects that could be expected from construction of the plan recommended by the Board of Officers for the elimination of shoaling in the vicinity of Head of Passes; and (b) the development of such other plans of improvement as might be suggested during the course of the model study.

## PART II: THE MODEL

### Area Reproduced

12. The Head of Passes model reproduced the 7-mile reach of the Mississippi River immediately above Head of Passes, all of South and Southwest Passes, the upper 2 miles of Pas a Loutre, and the upper one-half mile of Cubits Gap (see figs. 2 and 3, page 8). The model limits included sufficient overbank area to permit the reproduction of flow slightly higher than bankfull stages.

### Type of Construction

13. The problem in the Head of Passes area involved the phenomena of scouring and shoaling in the channel bed. The essence of the model study, therefore, was the simulation of bed-load movement, since relative developments in the bed configuration with the various plans in place were the criteria by which the most favorable plan would be determined. Consequently the model was of the movable-bed type, the bed material being free to move in simulation of bed-load movement in the prototype.

14. The channel bed within the movable-bed section was molded with crushed coal and the banks and overbank areas were molded in concrete to conform to the latest available prototype survey. The movable-bed section included the main river from the Head of Passes upstream to mile 4 (about 1 mile above Cubits Gap), the upper 2 miles of Pas a Loutre, and the upper 3 miles of South and Southwest Passes. The channel beds of the latter two passes were constructed in concrete from mile 3 to the Gulf,

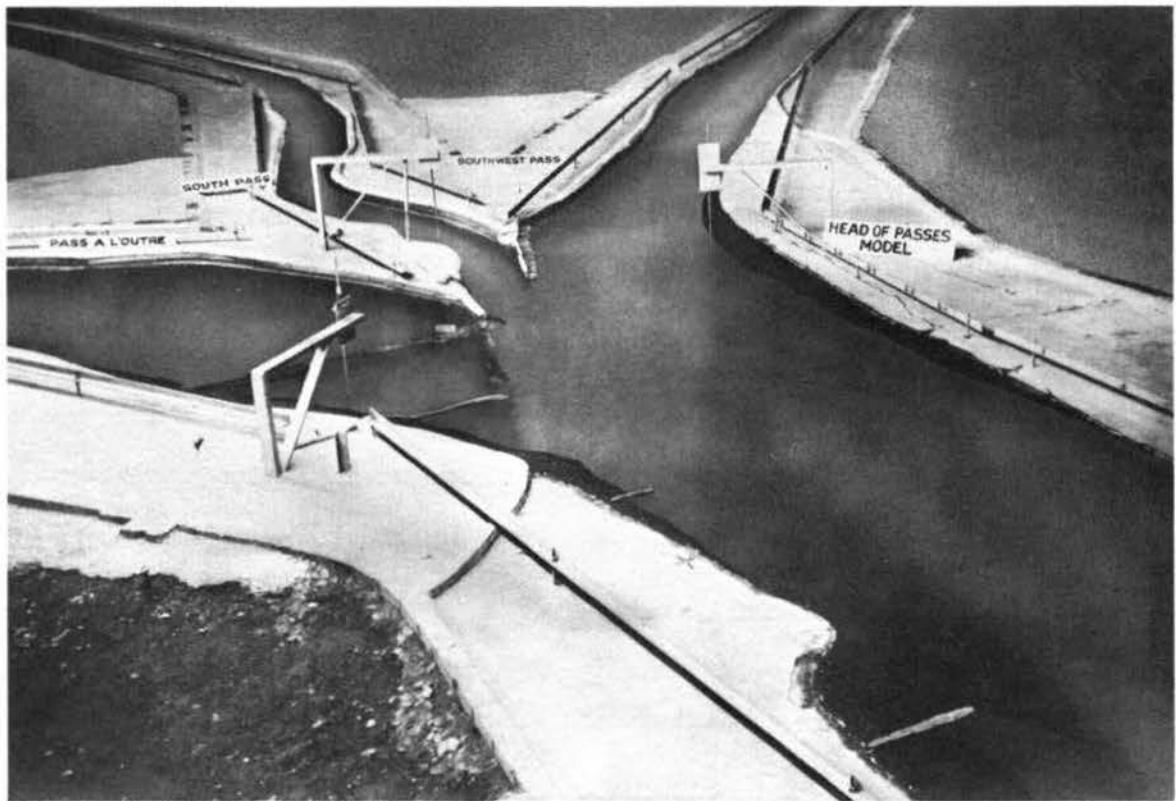


Fig. 2. Downstream view of the model showing the Head of Passes area

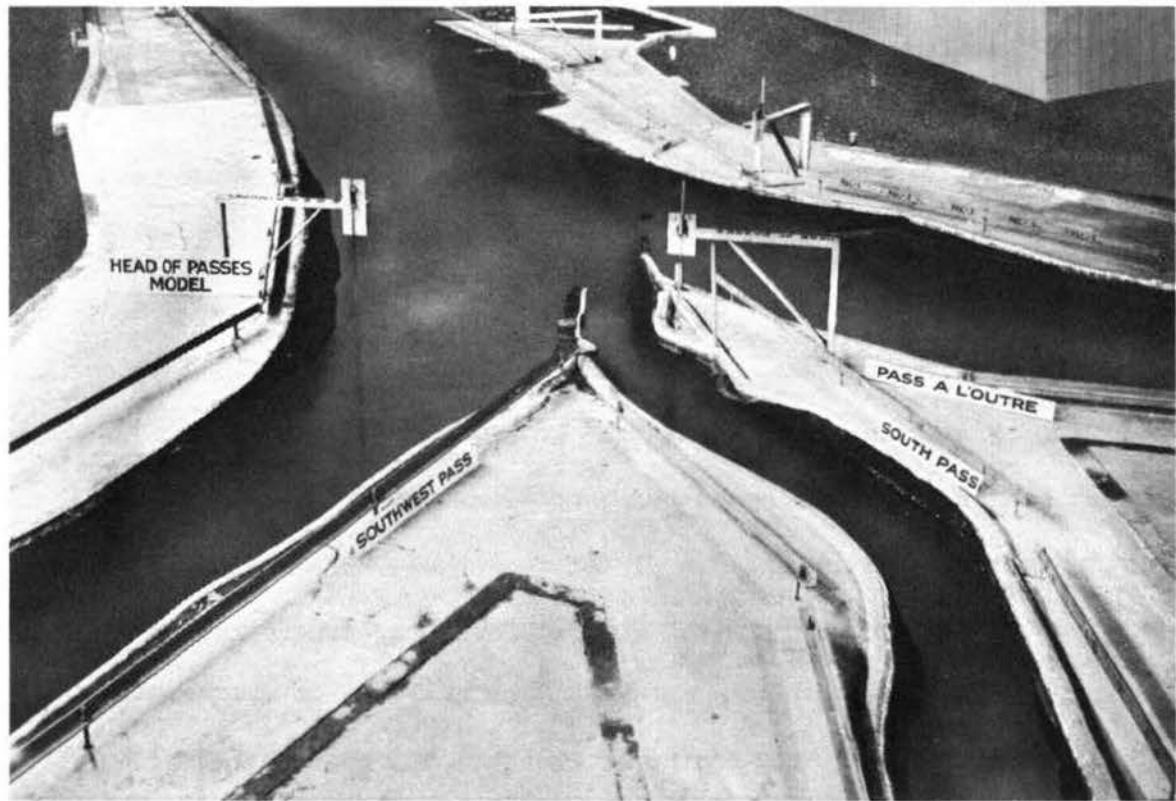


Fig. 3. Upstream view of the Head of Passes reach

with movable-bed traps installed at the upper ends of these fixed-bed reaches. Provisions were made for molding the movable bed to the contours of any desired prototype survey by means of plotted sheet-metal templets.

#### Scale Ratios

15. The model was constructed to linear scale ratios, model-to-prototype, of 1:500 horizontally and 1:150 vertically, with a resultant geometric distortion of 3.33. The model was constructed with a slight tilt, increasing the natural slope resulting from the selected scale ratios by about 0.0002. Other scale ratios such as time scale, discharge scale, etc., were determined empirically in the model. The selection of the linear-scale ratios was based largely upon the criterion that movable-bed material of the model must be moved by model stages corresponding to stages at which similar movement of bed material takes place in the prototype.

#### Appurtenances

16. The discharge supplied to the Head of Passes model in the reproduction of the discharge hydrograph was regulated by means of a manually operated valve; this discharge was measured by means of a venturi meter installed in the supply line. Cubits Gap and Pas a Loutre were regulated by means of a manually controlled valve to discharge any desired percentage of the Mississippi River flow. The discharges in South and Southwest Passes were controlled only by maintaining the water-surface elevations at mG1 at their lower ends; these water-surface

elevations were controlled by electrically operated valves and automatic control mechanisms.\* The discharge distribution through the passes was determined by means of calibrated orifices in the discharge lines. Water-surface elevations at various points along the main channel and along the channels in the passes were determined by point gages located at positions in the model corresponding to prototype locations and at critical control points.

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\* This apparatus is described in detail in paragraphs 16-18 of Waterways Experiment Station Technical Memorandum No. 2-244, "Plans for the Improvement of the St. Johns River, Jacksonville to the Atlantic Ocean; Model Investigation."

## PART III: DISCHARGE-DISTRIBUTION TESTS

17. The average discharge of Southwest Pass in the prototype decreased progressively from 39.5 per cent of the total discharge at Head of Passes in 1937 to 36.3 per cent in 1940, a decrease of 3.2 per cent. Discharge-distribution tests were considered desirable, before undertaking the tests of proposed improvement plans, in order to determine whether this decrease was caused by regulating works installed during the 1937-1940 period. In addition to the above, information was desired as to the effects of the dredge cut in Southwest Pass (then in progress) from mile 10.5 to the Gulf on discharge distribution within the three passes.

Test Procedure

18. The discharge-distribution tests involved only the study of the hydraulic characteristics of the river; therefore, before beginning these tests all supplementary slope (added tilt described in paragraph 15) was omitted from the model inasmuch as the proportional movement of bed material was not necessary. The model was first adjusted to reproduce 1937 discharge. This was accomplished with the model bed molded to conform to the prototype end-of-flood survey of 1937, and all regulating works existing in the prototype at the time of that survey installed in the model. Under these conditions, 12- to 17-ft stages were reproduced with the model adjusted to reproduce the average discharge distribution observed in the prototype during 1937. The data obtained during this series of stages were used to plot a stage-discharge curve for Pas a Loutre, based on the model gage at the head of this pass. The

discharge of Cubits Gap was maintained at 14.2 per cent of the total river flow for all of the discharge-distribution tests.

19. After adjustment and operation of the model, as described above, the bed of the model was molded to the prototype crest-of-flood survey of 1940, with all regulating works as of that date included in the model. Under these conditions, 12- to 17-ft stages were reproduced, with all model controls except that of Pas a Loutre remaining as adjusted in the test of 1937 conditions; for each stage the discharge of Pas a Loutre was adjusted to the stage-discharge curve obtained for that pass during the adjustment test (1937 conditions). This procedure was repeated, with the dredged cut in Southwest Pass (400 ft wide and 50 ft below mG1 from mile 10.5 to the Gulf) completed in the model.

#### Results

20. The results of the discharge-distribution tests, together with comparable prototype data, are presented in tables 1 to 5. The results of the discharge-distribution measurements taken in the model during the tests of proposed improvement plans are shown in table 6. Comparison of tables 1 and 3 and of tables 2 and 4 shows that the model provided an excellent check on the changes in percentile discharge distribution which occurred in the prototype between 1937 and 1940, thus definitely indicating that the reduction in discharge of Southwest Pass was caused by the spur dikes constructed within that pass during this period. Results of the discharge-distribution tests and discharge measurements taken during subsequent tests of proposed plans indicate that the over-all hydraulic resistance of any pass is the major

controlling factor in determining the discharge down the pass. This was indicated by the fact that none of the improvement plans proposed for construction at the Head of Passes, except plan R and its modifications, produced any appreciable change in discharge distribution among the passes. Model tests also indicated that the dredge cut in Southwest Pass from mile 10.5 to the Gulf (in progress at beginning of model study and completed in 1941) would restore to that pass about 2.1 per cent of the total discharge at Head of Passes (table 5).

21. At this point, a few additional tests of extreme conditions were made to check further into the general possibility of altering the percentile distribution of discharge among the passes by means of partial closures of the upper ends of Pas a Loutre and Southwest Pass. It was found that about 50 per cent of the cross-sectional area in the head of either of these two main passes could be blocked off by an impermeable dike without altering the discharge of any of the passes. These experiments were not extended to determine the degree of closure which would begin to affect the discharge. The results obtained substantiate the premise that the over-all hydraulic resistances of the passes themselves, rather than structures at Head of Passes, exercise almost complete control over the discharge distribution among the passes.

## PART IV: VERIFICATION OF THE MODEL

Principle of Model Verification

22. The value of this type of model study is dependent upon the ability of the model to predict with a reasonable degree of accuracy the action which can be expected to occur in the prototype under conditions similar to those established in the model during tests of proposed improvement plans. Therefore, before proposed improvement plans are studied, the model's ability to reproduce known prototype phenomena must be demonstrated. This procedure is known as the "verification" of the model.

23. Verification of a movable-bed model, such as the Head of Passes model, is concerned almost solely with adjustment of the movement of the material composing the model bed, so that the model material will move in a manner similar to that of the prototype material affecting the problem area. The obtaining of close similarity of bed-load movement usually requires slight departures from complete hydraulic similarity. For instance, because of the motility characteristics of model bed material it is usually necessary to flatten the slopes of the high stages slightly in the model; were this not done, movement of material at these stages would be so great as to be dissimilar to the movement in the prototype for corresponding stages. Among the factors that must be adjusted correctly to obtain a satisfactory model verification are the discharge scale, time scale, water-surface slopes, rates of introducing bed material, and roughness of fixed boundaries. The resultant end of these adjustments, or the "verification," is that the movement of the

model bed material is similar to the movement in the prototype under corresponding flow conditions.

#### Procedure

24. The verification procedure for a movable-bed model usually consists of the following steps: first, two prototype surveys of past dates are chosen -- the time between these surveys being known as the "verification period" -- and the movable bed of the model is molded to conform to the earlier survey; next, the hydrograph recorded for the prototype during the verification period is reproduced in the model to the proper time scale, all regulative measures (such as dike installations and dredging) undertaken in nature during that period being reproduced in the model at times corresponding to their occurrence in the prototype. The model is considered verified if, at the end of the verification period, the bed configurations as shown by the later prototype survey have been accurately reproduced.

25. The verification period for the Head of Passes model was taken as the time between the prototype end-of-flood survey of June 1937 (see plate 1) and the end-of-flood survey of May 1939 (see plate 3). Before beginning the verification test, the movable bed of the model was molded to the prototype end-of-flood survey of 1937, and all regulating works existing in the prototype at the time of that survey were reproduced. The model was then operated by reproducing the hydrograph recorded at the Carrollton gage during the verification period (see plate 2). During this operation movable-bed material was introduced continuously at the upper extremity of the model at a rate determined during earlier

adjustment tests; all regulating and maintenance works (including dredging) which were undertaken in the prototype during the verification period were simulated in the model at times corresponding to their occurrence in the prototype. A survey of the model bed was made at the completion of the verification hydrograph for comparison with the 1939 end-of-flood prototype survey.

#### Discharge distribution

26. The model discharge distribution used for the verification test followed the average percentile distribution of flow observed in the prototype during the period 1937-39, as furnished by the New Orleans District. Cubits Gap was controlled to discharge 12.3 per cent of the total river flow at that point; Pas a Loutre, South Pass and Southwest Pass were adjusted to discharge 44.0, 18.3, and 37.7 per cent, respectively, of the total river flow at Head of Passes.

#### Results

27. The accuracy with which the model reproduced the changes in bed configuration occurring in the prototype during the verification period can be determined from a comparison of the model survey shown on plate 4 with the corresponding prototype survey shown on plate 3. The principal discrepancy noted in the problem area during the verification test was in the area near mile 0 just above and to the right of the West Headland dike, where model depths were somewhat less than those shown by the prototype survey. Other discrepancies noted were along the left bank just above mile 1 of the main river, where depths were again somewhat less than in the prototype, and in the midstream area near the head

of Cubits Gap (above mile 3) where the central area shoal did not develop as extensively in the model as it did in the prototype.

28. In general, the results of the verification test are considered an excellent reproduction of the configurations shown by the prototype survey. Although some differences were obtained between actual model and prototype soundings, it will be noted that all of the important tendencies were well reproduced. The results of the final verification test indicate that the adjustment of the model was sufficiently accurate to permit reliable testing of proposed improvement plans.

## PART V: TESTS OF PROPOSED IMPROVEMENT PLANS

29. The testing program involved a "base test" (test of existing prototype conditions), and tests of 27 proposed improvement plans for the Head of Passes area. The improvement plans tested included the plan recommended by the Board of Officers (see paragraph 11), modifications of this plan, and other plans that appeared to offer possible solutions of the problem at Head of Passes. Certain of the plans tested were devised by engineers of the Mississippi River Commission and of the New Orleans District, who observed much of the model operation, and others by engineers of the Waterways Experiment Station. A sufficiently wide range of possible systems of improvements was tested to provide a comprehensive study of the problem.

Test Procedure

30. The base test and the test of each proposed improvement plan were begun with the model bed molded to the configuration of the prototype 1940 crest-of-flood survey, and all regulating works existing in the prototype at that time were reproduced in the model. Each improvement plan under study was installed in the model after the bed was molded but prior to the beginning of operation.

Model hydrograph

31. The hydrograph used for each run (one simulated year) of the tests of improvement plans consisted of the reproduction of an average stage hydrograph compiled from prototype records of the 10-year period from 1931 to 1940. The hydrograph as compiled from the prototype records

was arranged in a series of constant stages suitable for reproduction on the model but following as closely as practicable the magnitude and sequence of the stages of the average prototype hydrograph. The model hydrograph and the average prototype hydrograph on which it was based are shown on plate Al of the appendix to this report, together with a major-flood hydrograph used in special tests discussed in the appendix. Each test was continued through a sufficient number of runs to produce approximate stability of the movable bed, so that the ultimate effects of each plan would be indicated.

#### Discharge distribution

32. For all tests subsequent to the verification (except plan R and its three modifications) the following basic discharge distribution was used: Cubits Gap to carry 12.3 per cent of the total river flow at that point; Pas a Loutre, South Pass, and Southwest Pass to carry 44.0, 17.3, and 38.7 per cent, respectively, of the total river flow at Head of Passes. This distribution was based on the Southwest Pass 1937 discharge of 39.8 per cent, minus the 3.2 per cent decrease that occurred until 1940, plus the 2.1 per cent increase that model tests indicated would be effected by the dredge cut in Southwest Pass from mile 10.5 to the Gulf. Thus, it was assumed for all tests that this dredge cut was completed and maintained throughout the period involved. The model was operated with Cubits Gap and Pas a Loutre controlled to discharge the above percentages of flow, and with no control exercised over South and Southwest Passes discharges other than that of maintaining the water surfaces at their lower ends constant to mgL.

Base Test (Test 2)Description

33. The purposes of the base test or test of existing prototype conditions were: (a) to determine the degree of channel deterioration under existing conditions in the prototype with no maintenance dredging or other improvement; and (b) to provide a basis of comparison for the results of subsequent tests of proposed improvement plans. A comparison of the results of the base test with results of the tests of an improvement plan will indicate the effects of the improvement works tested. The base test followed the general procedure described in paragraphs 30 to 32. Since this involved the study of existing prototype conditions, no improvements (other than those existing in the prototype at the time of the 1940 survey) or maintenance dredging were simulated during the test.

Results

34. The final results of the base test are shown on plate 6 and photograph 1. The results of this test can be determined from a comparison of plate 5, showing the condition of the model bed at the start of the test, with plate 6, showing the condition of the model bed at the end of the test. The principal effects noted during the base test are described in the following paragraphs.

35. Channel above the Head of Passes. The channel above the Head of Passes remained fairly stable during the test. The depths over the shoal area along the middle of the channel below Cubits Gap were increased somewhat over those shown by the 1940 prototype survey to which

the model bed was molded. It is believed that this unusual shoal area shown on the prototype survey was probably the result of an abnormal amount of material moved into this area, and that under normal conditions project depths would be maintained. Some scouring was noted along the left bank below Cubits Gap; this tendency was also noted during the verification test and no appreciable change can be expected in this vicinity.

36. Southwest Pass. The channel at the entrance to Southwest Pass shoaled to 30-ft depths. Heavy shoaling occurred in the dredged cut along the right bank at the entrance to Southwest Pass, completely filling the upper end of the cut. Although the lower end of the dredged cut at the entrance to Southwest Pass did not fill completely in the model, it is believed that cut would be completely shoaled in the prototype; the failure of the dredged cut in the model to shoal completely is attributed to the fact that no attempt was made on the model to reproduce sedimentation of material in suspension. A slight tendency to scour a channel near the entrance range in the vicinity of mile 0 was noted during runs 6 and 8; however, project depths were not obtained. No appreciable change occurred in the channel below the head of Southwest Pass between miles 1 and 3. A decrease in the width of the 40-ft channel was noted near mile 2.5. The decrease in depths in this vicinity, which was noted as early as run 2, was not more than 3 or 4 ft at the end of run 8 (end of test), and no serious shoaling is indicated at this point.

37. South Pass. The entrance at the head of South Pass remained shoaled to less than project depths until the end of run 6; then a channel was scoured along the East Headland dike. By the end of the test,

the shoal area moved downstream into the pass and project depths were obtained along the entrance range into South Pass. Indications are that under normal conditions of flow the channel at the head of South Pass will be maintained at project depths and the shoaling existing in the prototype at the time of the 1940 prototype survey will eventually disappear. A tendency to fill the scour hole in South Pass below the West Headland dike was noted during run 6, and depths of only 62 ft were obtained at the end of the test. However, the accuracy of model depths within this scour hole is doubtful, partly because accurate details were lacking on the configuration of the side banks of the scour hole in the prototype. No important tendencies were noted in the channel below the scour hole.

38. Pas a Loutre. The depth of the scour hole below the Pas a Loutre sill was 112 ft at the end of run 4, 123 ft at the end of run 6, and 103 ft at the end of the test, indicating the depth of the hole to be somewhat unstable. Some changes in the configuration of the channel bed in Pas a Loutre were noted during the test. However, a comparison of the tendencies in the verification test with those of the base test indicates that under existing conditions the Pas a Loutre channel would remain fairly stable.

#### Plans A, B, and C

##### Plan A (test 3)

39. Description. Plan A was the first of two plans submitted for study at the time of inception of the model study. It was designed to eliminate as many as possible of the unfavorable conditions existing in

the vicinity of Head of Passes. The plan (shown on plate 7) involved:

(a) construction of a spur and trail dike from West Headland dike No. 1 to eliminate shoaling at head of Southwest Pass; (b) removal of False Point at head of South Pass to improve the entrance channel and eliminate the existing eddy and scour hole; (c) removal of sections of the Pas a Loutre submerged dike and sill to reduce the attack on East Headland and eliminate the large scour hole below the submerged dike and adjacent to East Headland; (d) extension of the lower left-bank dike at the head of Pas a Loutre to counteract any possible tendency for increase in Pas a Loutre discharge as a result of the contraction of the entrance to Southwest Pass; and (e) installation of an initial dredge cut to increase the efficiency of the entrance channel into Southwest Pass and eliminate annual maintenance dredging.

40. Results. Test results indicated that Plan A (see plate 7) would not produce the desired effects in the vicinity of Head of Passes. The results are described in detail in the following subparagraphs.

- a. Above Head of Passes. Some shoaling occurred just below Cubits Gap during the first two runs of the test but soon disappeared, and, by the end of test, the channel in this vicinity was in about the same condition as that obtaining at the end of the base test.
- b. Southwest Pass. The dredged cut at the entrance to Southwest Pass was shoaled almost completely by the end of the test. The contraction works along the West Headland produced only a local effect on the shoal area at the entrance to Southwest Pass and did not provide a navigable channel through the shoal area. Depths were increased and maintained along the trail dike; however, the channel immediately above was maintained at controlling depths of only about 33 ft below mG1 along the alignment of the dredge cut. The area to the left of the dredged channel and above the trail dike shoaled to about the same condition as in the base test. The depths in Southwest Pass below the head increased somewhat,

probably because of the decrease in amount of material moving into the pass, and the shoaling noted in the base test near mile 2.5 was not obtained during this test.

- c. South Pass. The removal of False Point at the head of South Pass considerably improved the alignment of the currents in that vicinity. The cross-sectional area of the channel was increased, resulting in considerable shoaling along the West Headland. The main currents entering South Pass moved along the east bank forming the deepest channel along that side. Slack water existed just above and over the scour hole below the West Headland dike, but since sedimentation of material in suspension was not simulated in the model, very little material was deposited in the hole. The portion of South Pass below the scour hole remained fairly stable throughout the test.
- d. Pas a Loutre. The gap in the Pas a Loutre sill and in the deflecting dike did not produce the desired effect of filling the deep hole below the sill. The large eddy off the end of East Headland prevented any material from being deposited in the hole. Neither did the gap have the desired effect on the Pas a Loutre channel below the sill. The amount of material moving into Pas a Loutre was increased by about 10 per cent with a corresponding decrease in the material moving into South and Southwest Passes.
- e. Discharge distribution. The discharge distribution in South and Southwest Passes remained practically constant throughout the test. The installation of this plan in the model had no perceptible effect on stage heights either in the main river or in any of the passes. The discharge distribution in the passes is presented in table 6.

#### Plan B (test 4)

41. Description. Plan B (plate 8) was a modification of plan A; the only difference in the two plans was that in plan B the West Headland structure was removed and False Point was left as existing in the prototype. The features of plan B included the following: (a) extension of the lower left-bank dike at the head of Pas a Loutre 1400 ft as a permeable dike, with a 150- by 250-ft mat at the outer end; (b) removal

of sections of the submerged deflecting dike and submerged sill at head of Pas a Loutre to -40 ft mGl; (c) removal of the entire West Headland structure to a depth of -40 ft mGl for a distance of 1800 ft; (d) dredging of a channel along the west bank and into Southwest Pass, bottom of cut 400 ft wide and 60 ft below mGl, with side slopes of 1 on 5. The operating procedure for this test was the same as that of plan A except that in this test the sides of the gap in the submerged sill and in the submerged deflecting dike at the head of Pas a Loutre were molded in gravel which was free to fall in simulation of sloughing. This test was operated for 12 runs.

42. Results. In general the results of this test, given in detail in the following subparagraphs, indicate that plan B would have no appreciable effect on channel conditions in the Head of Passes area and would not reduce shoaling in the entrance to Southwest Pass.

- a. Above Head of Passes. The removal of the West Headland structure had no effect on the channel above Head of Passes. As in the test of plan A, some shoaling occurred near the lower end of Cubits Gap but disappeared by the end of run 4. Except for some increase in depths over the shoal area along the center of the channel below Cubits Gap, the channel above Head of Passes remained fairly stable during the test with no appreciable change from base-test conditions indicated.
- b. Southwest Pass. The channel at the entrance to Southwest Pass shoaled to about the same condition as in the base test. Heavy shoaling occurred in the dredged cut along the right bank at the entrance to the pass, completely filling the upper end of the cut. Because of the fact that the model did not reproduce material in suspension, the lower end of the dredge cut was not filled completely. Some shoaling occurred in the Southwest Pass channel near mile 2.5; however, a similar condition was obtained during the base test and is not considered a result of the improvement plan.
- c. South Pass. An entrance channel of more than 40-ft

central depth was obtained into South Pass. No reduction was noted in the size of the scour hole below False Point.

- d. Pas a Loutre. The gap in the Pas a Loutre sill and in the deflecting dike produced no noticeable effect on the scour hole below the sill nor on the channel within the model limits. The amount of material moved into Pas a Loutre was increased by about 10 per cent over that of the base test with corresponding decreases in South and Southwest Passes.
- e. Discharge distribution. The discharge distribution in South and Southwest Passes remained fairly constant throughout the test with no change from existing conditions indicated. The installation of plan B in the model had no measurable effect on stage heights in the main river or in any of the passes. The results of discharge measurements in the three main passes are shown in table 6.

#### Plan C (test 5)

43. Description. Plan C was designed as an alternate to plan B, the only difference being that plan C included the removal of False Point at the entrance to South Pass (see plate 9). The procedure for this test was the same as that for the test of plan B with the exception that this test was discontinued before the model bed had reached stability.

44. Results. The results of this test indicated that removal of False Point would not affect channel conditions in the Head of Passes area. During the early runs of the test, it became evident that its results would be similar to those of the test of plan B and that the removal of False Point would tend to increase rather than diminish the shoaling at the entrance to South and Southwest Passes. The test was therefore discontinued at the end of run 6.

#### Plans D, E, F, G, and N

#### Plan D (test 6)

45. Description. Plan D (see plate 10) involved the construction

of right-bank dikes, starting the contraction of the channel above Cubits Gap where the channel depths begin to decrease and ending below the entrance to Southwest Pass. The plan included the following features: (a) construction of 18 permeable dikes along the right bank from mile 4.9 above Head of Passes to mile 1.1 below Head of Passes into Southwest Pass; (b) the lower left-bank dike above Pas a Loutre extended 1400 ft as permeable dike; (c) area between proposed right-bank dikes and below extension to the left-bank dike filled to mGl with 1-on-5 slopes ending 50 ft from outer ends of dikes; (d) sections of submerged deflecting dike and submerged sill at the head of Pas a Loutre removed to -40 ft mGl; (e) channel dredged along the west bank and into Southwest Pass, bottom of cut 400 ft wide and 60 ft below mGl with side slopes of 1 on 5. No dredging was simulated in the model after the start of the test. The model was operated for 12 runs.

46. Results. The results of the test of plan D (see plate 10), given in following subparagraphs, indicate that the right-bank dikes would produce an increase in the general depths over the channel bed above Head of Passes but that the contraction in the head of Southwest Pass would not be sufficient to produce any appreciable change from base-test conditions.

a. Above Head of Passes. The right-bank dikes produced considerable scouring of the channel from Cubits Gap to just above Head of Passes. The materials scoured from this area completely filled the upper end of the dredged cut and shoaled the channel along the left bank just above the entrance to Pas a Loutre. The shoal area along the center of the channel below Cubits Gap, as noted in the 1940 prototype survey to which the bed of the model was molded before beginning this test, almost completely disappeared; by the end of the test only two small areas slightly less than 40 ft deep were obtained in this

vicinity. The shoal area just above Pas a Loutre disappeared during the test, but the upper end of the dredged cut remained shoaled, indicating that such a cut would not be obtained without periodic dredging.

- b. Southwest Pass. The right-bank dikes had little effect on shoaling at the entrance to Southwest Pass. The excess material moved from the scoured area upstream (described in the preceding subparagraph) caused considerable shoaling to occur at the entrance to the Southwest Pass during the first part of the test, but most of this material had been moved out by the end of the test. Movement of material was not sufficient to produce a channel of project depth in the entrance to the pass. The channel below the head of Southwest Pass remained fairly stable throughout the test with no unusual shoaling noted at mile 2.5.
- c. South Pass. A large shoal area formed at the entrance to South Pass during the early part of the test. As the channel above Head of Passes became stabilized, the material forming the shoal was moved into the channel to fill the deep scour hole below False Point and shoal the channel immediately downstream to less than 35-ft depths. However, it is not believed that the scour hole thus filled would remain filled permanently. The channel downstream from this point remained fairly stable.
- d. Pas a Loutre. No material change occurred in Pas a Loutre. Most of the increase in the amount of material moved downstream from the channel above was moved through Pas a Loutre with the remainder deposited in the upper ends of South and Southwest Passes.
- e. Discharge distribution. The discharge distribution remained fairly constant throughout the test with no change from base-test conditions indicated. The installation of the right-bank dikes of plan D did not affect stage heights in the Head of Passes area and above sufficiently to indicate that any change in discharge distribution would occur in any of the passes. The results of discharge measurements taken during this test are presented in table 6.

#### Plan E (test 7)

47. Description. Plan E was similar to plan D except that the alignment of the dredge cut at the head of Southwest Pass for plan E was revised so as to follow a line more nearly parallel to the main river

currents (see plate 11). The features of this plan are as described in paragraph 45 for plan D.

48. Results. The results of this test (see plate 11) were similar to those of the test of plan D described in paragraph 46. The change in the alignment of the dredge cut at the entrance to Southwest Pass had no noticeable effect on the channel in the Head of Passes vicinity.

#### Plan F (test 8)

49. Description. Plan F was similar to plans D and E except that the right-bank dikes were extended in an effort to increase the velocity and the depth of the channel at the head of Southwest Pass (see plate 12). In plan F the main river channel was contracted to 3,200 ft above Cubits Gap, to 3,100 ft just below Cubits Gap, and to 2,900 ft from Pilottown to Head of Passes; Southwest Pass was contracted to 1,800 ft at the upper end and to 1,600 ft at the end of the dike system. The model was operated for 14 runs before stability of the channel bed was attained.

50. Results. The results of this test (see plate 12), given in the following subparagraphs, indicated that the contraction works of plan F would not be sufficient to produce a satisfactory channel.

a. Channel above Head of Passes. Violent scour of the channel bed above Head of Passes was noted during the early part of the test, with depths well over 40 ft obtained across the full width of the channel by the end of the test. The large amount of material moved downstream from this area shoaled the entrance to South and Southwest Passes.

b. Southwest Pass. As the channel upstream became stable, the material forming the shoal at the head of Southwest Pass was scoured and a 40-ft channel about 800 ft in width was obtained in the entrance to the pass by the end of run 8. By the end of the test a bar of less than

35-ft depths formed at the upper end of the entrance channel closing off the 40-ft channel in that vicinity. The formation of the point bar decreased the width of the 35-ft channel along the West Headland dike to about 400 ft. The dredged cut along the right bank into Southwest Pass was completely filled, with the channel forming to the left. No appreciable change from base-test conditions was indicated in the channel below the entrance.

- c. South Pass. The material forming the shoal at the entrance to South Pass was moved into the channel downstream filling the scour hole and shoaling the channel to less than 35-ft depth immediately downstream.
- d. Pas a Loutre. The material moved into Pas a Loutre was increased as in previous tests in which the sill and deflecting dike were gapped. No material reduction of the scour hole below the sill was noted.
- e. Discharge distribution. The discharge distribution remained fairly constant throughout the test with no change indicated. Installation of the right-bank dikes did not affect appreciably stage heights in the Head of Passes area. Discharge distributions in the three main passes are presented in table 6.

#### Plan G (test 9)

51. Description. Plan G was similar to plan F (see paragraph 49) except that in this plan the West Headland structure was removed to a depth of 40 ft below mG1 (see plate 13). The test consisted of 12 runs.

52. Results. In general, the results of the test of plan G (without West Headland) were the same as plan F (with West Headland) (see plate 13). A channel of more than 40-ft depth was obtained across the full width of the channel above Head of Passes. Considerable shoaling occurred across the entrance to South and Southwest Passes at the beginning of the test. By the end of run 4, the entrance channel at the head of Southwest Pass was completely shoaled to less than 35-ft depths. As the channel upstream became stable, scouring occurred over the bar at the entrance to the pass, forming a 35-ft channel of 400-ft width.

Shoaling at mile 2.5 in Southwest Pass almost closed off the 40-ft channel at that point. A channel of over 40-ft depth was scoured along the left bank of the entrance to South Pass leaving a bar of less than 35-ft depths between that channel and the channel into Southwest Pass. The large amount of material moved into the channel from upstream filled the scour hole just below False Point. No material change occurred in Pas a Loutre. Except for the formation of the bar above the exposed point between the entrances to South and Southwest Passes, the removal of the West Headland structure had no effect on channel conditions in the Head of Passes area. The removal of the West Headland eliminated some contraction in that vicinity and increased the shoaling tendency just above the entrance to the two passes.

Plan N (test 16)

53. Description. Plan N (see plate 14) consisted of: (a) the construction of 18 permeable dikes along the right bank from above Cubits Gap to below the head of Southwest Pass; (b) the extension of the lower left-bank dike at the head of Pas a Loutre 1400 ft as a permeable dike; and (c) the maintenance of 32-ft depths into South Pass and 35-ft depths into Southwest Pass by dredging at the end of each two years of operation as required. Channel depths into South Pass were maintained over a bottom width of 400 ft and into Southwest Pass over a bottom width of 600 ft. Alignments of the dredge cuts varied during the test to follow the deepest water on smooth alignments. The dredge spoil was placed between and near the outer ends of the three dikes opposite the West Headland structure.

54. Results. Results of this test (see plate 14) indicated that

plan N would effect a 35-ft self-maintained channel of 600-ft minimum width after the initial development of the plan. The shoaling at mile 2.5 was not serious, and evidence of scouring was noted in the area at the end of the test. Depths in the channel above Head of Passes were increased during the test. The shoal area along the center of the channel was scoured, with depths of more than 40 ft obtained. During the early stages of this test considerable material was moved from upstream to shoal the entrance channels to South and Southwest Passes to less than 35-ft depths. Channel depths into South Pass were maintained with only a small amount of dredging at the ends of runs 2 and 4. Channel depths into Southwest Pass were maintained by dredging at the ends of runs 2, 4, 6 and 8. By the end of run 10, a self-maintained 35-ft channel of about 600-ft width was obtained with some improvement noted by the end of the test. Shoaling along the left bank of Southwest Pass near mile 2.5 closed off the 40-ft channel at that point. The increase in the amount of material moved into South Pass from upstream filled the scour hole below False Point.

Plans H, I, J, K, L, M, and T

Plan H (test 10)

55. Description. The features of plan H (see plate 15) were:

(a) dredging of a 60-ft-deep channel, with bottom width of 400 ft and side slopes of 1 on 5, from just above Cubits Gap to just below the entrance to Southwest Pass, passing close to the right bank in the entrance to the pass; and (b) placing of fills along the left bank below Cubits Gap and along the West Headland structure. The fills were

constructed of dredge spoil, and no protection against scour was provided. (This plan was that recommended by the Board of Officers, see paragraph 11, for improvement of the Southwest Pass channel in the vicinity of Head of Passes.) The test consisted of 12 runs.

56. Results. The results of this test (see plate 15 and photograph 2) indicated that the unprotected fills included in plan H would be scoured and the dredge cut would eventually be completely filled. Since none of the improvement works would be permanent, the ultimate condition of the channel would be the same as if no improvement works had been constructed. Detailed results of plan H were as follows:

- a. Channel above Head of Passes. The fill along the left bank below Cubits Gap was scoured from the start of the test. A channel of more than 40-ft depth was obtained through the fill area by the end of the test. Some scour was noted along the right of the channel below Cubits Gap during the early runs of this test; however, as the fill along the left bank was scoured some shoaling occurred along this side, filling the dredged channel to less than 50-ft depth. Except for some shoaling which occurred along the left bank, the material forming the fill upstream was moved completely out of the main river channel above Head of Passes.
- b. Southwest Pass. Scouring of the fill along the West Headland structure removed most of the material placed in the fill at that point. Some shoaling occurred in the dredged cut at the entrance to Southwest Pass from the start of the test. Although a 40-ft channel remained open in the dredged cut until the end of run 8, the channel had shoaled to a controlling depth of 35 ft by the end of the test.
- c. South Pass. The increase in the amount of material moved from upstream formed a bar of less than 35-ft depth across the entrance to South Pass. The material which moved into the pass filled the scour hole below False Point and almost closed off the channel just downstream.
- d. Discharge distribution. No material change in discharge distribution was noted during this test. The percentage of discharge in each of the three passes is presented in table 6.

Plan I (test 11)

57. Description. Plan I (see plate 16) was a modification of plan H to include larger fills along the left bank below Cubits Gap and at the West Headland, protection of the fills with simulated mat, and removal of False Point at the head of South Pass. The fills were constructed to top elevation of +4 ft mGl with side slopes of 1 on 5. With the exception of the Pilottown slip (left bank between miles 1.7 and 1.2) the sides of the fills were revetted with riprap extending 100 ft out from the toes of slopes. False Point was removed to -45 ft mGl with the side slope of 1 on 5 revetted with mat extending 100 ft from toe of slope. The small section of the West Headland structure extending above the slope of the fill was removed.

58. Results. The results of this test (see plate 16 and photograph 3) indicated that with plan I installed depths would be increased in the channel above Head of Passes but that a satisfactory channel through the entrance to Southwest Pass would not be obtained.

a. Area above Head of Passes. Considerable scour occurred in the channel bed above Head of Passes after the start of the test with depths generally increased over the entire area; only two small areas of slightly less than 40-ft depths were obtained by the end of the test. The intense movement of material during the early runs obliterated completely all signs of the dredge cut. The unprotected fill at the Pilottown slip was scoured with considerable caving of the bank; by the end of the test the top bank of the fill had receded as much as 400 ft. No excessive scour was noted along the toe of the protected fill in this area.

b. Southwest Pass. The dredged channel at the entrance to Southwest Pass began to shoal from the start of the test. By the end of the test the dredged channel had shoaled to less than 30-ft depths. Considerable scour occurred along the fill at the West Headland dike and to the left of the dredged channel, endangering the stability of the

fill. Except for a bar which formed at the upper end of the fill, a channel of more than 40-ft depth and 1,000-ft width was obtained at the end of run 4. Scouring near the upper end of the fill reached a depth of 86 ft below mGl. The material from this scour hole was deposited near the lower end of the fill forming a split channel at that point. By the end of the test the controlling depth through the entrance channel was only 36 ft. Some increase in the depths of the channel below the head of Southwest Pass was obtained during this test.

- c. South Pass. Currents moving into South Pass formed a large eddy near the upper end of the fill, scouring a hole of 70-ft depth near that point. A study of these currents indicated that the fill would form a serious hazard to navigation entering that channel. Considerable shoaling occurred in the South Pass channel; depths of less than 35 ft were obtained just below the entrance and near mile 2.4. The scour hole below the head of South Pass was filled completely.
- d. Discharge distribution. The discharge distribution in the three main passes was not affected by the installation of plan I. Results of discharge measurements made during the test are presented in table 6.

#### Plan J (test 12)

59. Description. Plan J (see plate 17) was similar to plan I, with slight modifications of that plan made in an attempt to produce a satisfactory channel at the entrance to Southwest Pass and to eliminate the undesirable conditions obtained in the test of the former plan. These modifications were: (a) the entire fill along the left bank of the main stream was protected with riprap extending 200 ft from toe of slope; (b) the fill at the West Headland structure was extended a shorter distance upstream than in plan I in an effort to obtain a better alignment of currents entering South Pass and to eliminate undesirable eddies as far as possible; (c) the fill at West Headland and the exposed bank after the removal of False Point were protected with riprap extending 200 ft from toes of slopes; and (d) dredging required for the

construction of the fills described above was not simulated during this test. The test consisted of 16 runs.

60. Results. Results (see plate 17) of this test indicated that plan J would increase the depths of the channel along the fill at the head of Southwest Pass. However, some periodic maintenance dredging would be required to maintain a suitable channel for navigation through the entrance to Southwest Pass. The scour holes at the upper end of the fill, noted in the test of plan I, were eliminated with a considerable improvement in the alignment of the currents entering the South Pass. Heavy scouring occurred in the channel above Head of Passes increasing the depth of the channel. The excessive movement of material from upstream during the early part of the test completely shoaled the channel across South and Southwest Passes to less than 35-ft depths. As the channel upstream became stable a channel of 40-ft depth was obtained through the entrance to Southwest Pass. A bar of less than 35-ft depths which formed immediately above the entrance to Southwest Pass limited the widths of the 35- and 40-ft channels at that point; below the upper end of the pass a 40-ft channel of more than 400-ft width was obtained. Shoaling at mile 2.5 in Southwest Pass formed a split in the channel in that vicinity. A 35-ft channel was scoured through the entrance to South Pass by the end of the test; however, a bar which formed along the East Headland resulted in an unfavorable alignment of the channel. The increase in the material moved into South Pass filled the scour hole below the entrance and shoaled the channel downstream.

Plan K (test 13)

61. Description. Plan K was the same as plan J except for the

type of mat used in protecting the fills. In plan K (see plate 18) the fill along the left bank below Cubits Gap, and the upper end and Southwest Pass side of the fill at the West Headland structure were protected with a simulation of asphalt mat. The South Pass side of the fill at the West Headland was protected with riprap as in plan J.

62. Results. Plan K produced an increase in the channel depths above Head of Passes but a satisfactory channel into Southwest Pass was not obtained. It is believed that the results of plan K would have been similar to those of plan J had a failure in the mat at the head of Southwest Pass not occurred. The results of this test (plate 18) indicated that the type of mat used would not in itself affect appreciably the final results. The channel above Head of Passes was in about the same general condition as in the test of plan J. The heavy movement of material from above completely shoaled the entrance to South and Southwest Passes during the early runs. Considerable scour was obtained in the channel along the proposed fill at the West Headland dike. The resulting channel, however, was insufficient in width and unfavorable in alignment for navigation. Primarily because of mat failure, a hole more than 90 ft in depth was scoured along the fill; the material scoured out of this hole was deposited near the lower end of the fill, forming a split channel at that point. Shoaling in Southwest Pass at mile 2.2 decreased the width of the 35- and 40-ft channels at that point. With the exception of the bar which formed above the entrance channel to South Pass, more than sufficient depths were obtained at the head of and into South Pass. The excess material moved into South Pass filled the deep scour hole below the entrance and slightly shoaled the channel downstream.

Plan L (test 14)

63. Description. The features of plan L (see plate 19) were similar to those of plan K except that the fill at the West Headland structure did not extend into South Pass, and False Point at the head of South Pass was not removed.

64. Results. The results of this test (plate 19) were similar to those of plan K. The failure in the simulated asphalt mat was not believed to be indicative of a failure in the prototype since the mat used was not an exact reproduction of a prototype asphalt mat. Observation of currents during this test did not indicate sufficient attack on the fill at West Headland to produce similar failures in the prototype. The effects of plan L on the channel above Head of Passes were generally the same as for all other tests that included the fill along the left bank below Cubits Gap. The entrance channels to South and Southwest Passes were shoaled just above the fill to less than 35-ft depths at the beginning of the test. As the channel upstream became stable, a 40-ft channel of 500-ft minimum width was obtained at the head of Southwest Pass. A scour hole of more than 100-ft depth occurred near the upper end of the fill at the West Headland structure. A bar which formed near the lower end of the fill resulted in a split channel at that point with each side less than 35 ft in depth. Shoaling in Southwest Pass near mile 2.2 decreased the width of the 35- and 40-ft channels at that point. Except for a small bar which formed near the head of South Pass, a channel of more than sufficient depth was scoured along the entrance channel into South Pass. The scour hole below False Point was completely filled. Failure in the mat at the upper end of the fill at the West

Headland structure resulted in a scour hole of 83-ft maximum depth.

Plan M (test 15)

65. Description. Plan M (see plate 20) was designed as a further modification of plan H in an attempt to produce a self-maintained channel through the entrance to Southwest Pass. Plan M included the construction of fills at the second left-bank dike above Pas a Loutre, and at the first, fourth, and eighth of the West Headland spur dikes as extension to these dikes. The tops of the fills were constructed to an elevation of 5 ft below mGl with side slopes of 1 on 8. The crests of the fills were capped with groins of solid construction to an elevation 8 ft above mGl. The fills were encased with flexible mat (simulation of asphalt mat) extending 200 ft from toes of slopes. The dredging required for the construction of these fills was not simulated during the test.

66. Results. The results of this test (see plate 20) indicated that the features of plan M would produce a too abrupt change in the present channel. It is believed that the attack on the structures of plan M and the resulting scouring action would endanger their stability within a short time. Shoaling occurred in the channel above Head of Passes, almost closing off the 40-ft channel below Cubits Gap. A strong current attack was observed on the proposed fill and extension to left-bank dike, causing considerable local scouring. A maximum depth of 137 ft below mGl was obtained just above the fill; a strong eddy which formed below the fill scoured a hole 104 ft below mGl at that point.

67. Currents entering South and Southwest Passes impinged directly against the upper spur dike extension, scouring the channel bed to more than 100 ft below mGl. A tendency to form a point bar from the right

bank just above the extension to the first spur dike produced an angle in the alignment of the resulting channel. Two small bars of less than 35-ft depth formed near the lower dike extension. Shoaling also occurred along the right of the Southwest Pass channel below the entrance.

68. A channel of more than sufficient depth was scoured through the head of South Pass. The scour hole below False Point was completely filled; however, a scour hole formed upstream as a result of the eddy produced by the West Headland dike. Some shoaling occurred in South Pass below the entrance, almost closing off the 35-ft channel below False Point.

Plan T (test 25)

69. Description. Plan T (see plate 21) was a partial modification of plan H (described in paragraph 55), and involved the installation of: (a) extensions to the left-bank dikes between miles 2.5 and 0.2 of the main river; (b) a permeable dike and trail at the West Headland structure; (c) a dredged channel 60 ft deep over a bottom width of 400 ft from Cubits Gap into Southwest Pass; and (d) fills on the left bank between miles 2.7 and 0.6 and between West Headland structure and the proposed trail dike. The fills were constructed of material dredged within 5,000 ft of the spoil areas. The dredged channel described in (c) above was maintained to 60-ft depths for the first 6 runs by dredging at the ends of runs 2, 4, and 6 with the dredged material placed in the original spoil areas.

70. Results. The results of this test (plate 21) indicated that the fill placed along the proposed dike extensions would eventually be completely scoured and its effectiveness in maintaining a channel along

the alignment of the dredge cut would be lost. As the material along the left bank moved downstream the dredge cut would be completely shoaled, with the main channel forming along the left-bank dike extensions. The proposed dike and trail at the West Headland dike would produce only a local scour with the channel upstream shoaling to less than project depths.

71. Continuous scouring of material placed in the fill along the left bank below Cubits Gap occurred during the test. The dredged channel above Head of Passes was shoaled to less than 60-ft depths; however, scouring which occurred along the right bank produced channel depths of more than 50 ft from just below Cubits Gap to above Head of Passes. Most of the material scoured out of the fill along the left bank was moved along that bank into Pas a Loutre and South Pass. A large shoal area of less than 35-ft depths formed along the ends of the lower left-bank dike extensions from material scoured from upstream. The dredged channel into Southwest Pass shoaled to less than 35 ft just above the proposed trail dike; channel depths of more than 40 ft were maintained just below this point. Some shoaling occurred near mile 2.5 in Southwest Pass, decreasing the width of the channel. Sufficient depths were obtained in the entrance channel to South Pass, but the large amount of material moved into that pass from upstream filled the deep scour hole below the head and slightly shoaled the channel immediately below and between miles 2 and 3.

Plans P, O, and Q

Plan P (test 17)

72. Description. Plan P (see plate 22) included the construction

of 18 permeable dikes along the right bank, extension of the lower left-bank dike just above Pas a Loutre, and channel maintenance dredging as in plan N (see paragraph 53). In addition, plan P included the removal of the West Headland structure, and the construction of 5 dikes along East Headland above the South Pass entrance. During this test depths of 32 ft in South Pass over a bottom width of 400 ft and 35 ft in Southwest Pass over a bottom width of 600 ft were maintained by dredging at the end of every second run. Alignments of the dredge cuts varied during the test to follow the line of deepest water.

73. Results. A comparison of the results of this test (see plate 22) with those of plan N (paragraph 54) indicated that the removal of the West Headland structure permitted the formation of the point bar farther to the left, resulting in an unfavorable alignment of the navigable channel into Southwest Pass. Although the amount of shoaling in the entrance to Southwest Pass would be considerably reduced, satisfactory channel alignment could not be maintained without periodic dredging. The channel above Head of Passes increased in depth, depths of more than 40 ft being obtained across the entire width of the channel below Cubits Gap. The material scoured from the channel upstream shoaled the entrance channels to South and Southwest Passes to less than project depths during the first and second runs of the test. A narrow channel of unfavorable alignment formed along the ends of the proposed dikes on East Headland. Continual maintenance dredging failed to produce any improvement in ultimate condition of the channel. A large bar of less than 35-ft depths formed along the center of the channel near mile 2 in Southwest Pass, closing off the 40-ft channel in that vicinity. A sufficiently

deep channel was formed along the right bank at the upper end of South Pass, but some shoaling occurred in that pass near mile 2.

Plan 0 (test 18)

74. Description. Plan 0 (see plate 23) involved the removal of the West Headland structure, the construction of 4 permeable dikes (with trails on upper two dikes) along East Headland and dredging of the right bank at the head of South Pass to obtain an 850-ft clear channel width into the pass. The West Headland structure and the right bank at the head of South Pass were removed to a depth of 45 ft below mG1 leaving a side slope of 1 on 3 which was revetted with mat extending 200 ft out from the toe of slope. No dredging was simulated during this test.

75. Results. The results of this test (see plate 23) indicated that plan 0 would not produce a channel of sufficient depth into Southwest Pass, and that most of the shoaling in the channel would occur just above the contraction of the proposed dikes. The channel above Head of Passes was in approximately the same condition as that obtained in the base test. The channel above the entrance to South and Southwest Passes shoaled to less than 35-ft depth during the early part of the test and remained in about that condition throughout the test. Considerable scour occurred opposite the proposed dikes, reaching a depth of 80 ft below mG1. A narrow channel of more than 40-ft central depth was effected along the proposed dikes and into Southwest Pass. No definite tendency to maintain a stable channel into Southwest Pass below the head was indicated. A small bar of less than 30-ft depth formed along the left bank at mile 1.1 with the deep channel shifting to the right. A large bar of less than 35-ft depth formed in the Southwest Pass channel

near mile 2 splitting the 35-ft channel in that vicinity. Except for a narrow gut which formed along the end of the proposed dikes, the channel at the head of South Pass was shoaled to less than 35-ft depths. Considerable shoaling also occurred in the South Pass channel downstream near miles 1 and 2.

Plan Q (test 19)

76. Description. Plan Q (see plate 24) was a slight modification of plan O. The essential difference between plan O and plan Q was that in the latter plan the arrangement of the dikes along the East Headland was revised slightly and the lower left-bank dike above Pas a Loutre was extended. During this test 40-ft depths over a 600-ft bottom width were maintained by dredging at the end of each two years (runs) for the first 8 years of operation.

77. Results. The results of this test (plate 24) were similar to those of the test of plan O. Shoaling occurred above the contraction works along East Headland as in the previous test with only slight improvement in the controlling channel depths. The channel above Head of Passes remained fairly stable with no appreciable change from base-test conditions indicated. A persistent tendency to shoal the channel just above the proposed East Headland dikes was noted throughout this test. A hole of 89-ft maximum depth was scoured along the proposed dikes. A narrow 35-ft channel about 400 ft wide was obtained through the shoal area above the proposed dikes by the end of the test. The formation of the point bar opposite the head of South Pass resulted in an angle in the alignment of the channel into Southwest Pass. Considerable shoaling occurred along the right bank of South Pass from the head to about mile 2.2.

No substantial change in the discharge distribution was noted during this test (see table 6).

Plans R, R-1, R-2, R-3, and S

Plan R (test 20)

78. Description. Plan R (see plate 25) involved: (a) the extension of the East Headland as a permeable dike and the construction of 5 permeable dikes and trails along the East Headland as extended; (b) the extension of the second left-bank dike above Pas a Loutre as a permeable dike; and (c) the removal of the West Headland structure and a portion of the right bank at the head of South Pass leaving a clear channel width of 850 ft. The West Headland structure and the right bank at the head of South Pass were removed to a depth of 45 ft below mG1, leaving side slopes of 1 on 3 which were revetted with mat extending 200 ft out from toes of slopes. No dredging was simulated during the test.

79. Discharge distribution. Before undertaking formal testing of plan R, preliminary tests were made to determine the effects of this combination of structures upon discharge distribution among the three main passes. Results of these tests indicated that the Pas a Loutre discharge would be decreased 1.3 per cent by the combination of: (a) reduction in cross-sectional area of this pass by the East Headland extension and by the bar which formed below the extended left-bank dike; and (b) deflection of currents away from the mouth of the pass by these structures and the bar. The decrease in Pas a Loutre was carried largely by Southwest Pass. Accordingly, the test of plan R, as well as its modifications (plans R-1, R-2, and R-3), were conducted with Pas a Loutre,

South Pass, and Southwest Pass carrying 42.7, 17.1, and 40.2 per cent, respectively, of the total flow at Head of Passes (see table 6).

80. Results. No major change occurred in the channel above Head of Passes (plate 25) although considerable increase in depth was observed along the proposed left-bank dike extension above Pas a Loutre, and a bar formed below the extension partially blocking the entrance of this pass. Except for a deep channel along the ends of the proposed dikes along East Headland, the channel at the entrance to South and Southwest Passes was shoaled to less than 35-ft depth during the first run of the test. By the end of the test, a 35-ft channel of more than 800-ft minimum width was obtained into Southwest Pass. Shoaling at the head of Southwest Pass choked the 40-ft channel at that point to a controlling depth of 38 ft. Some shoaling occurred along the left bank of Southwest Pass near mile 2 which decreased the width of the project channel. A bar at the head of South Pass formed a split channel into the pass, each side being more than 40 ft in depth. Shoaling in South Pass decreased the width of the channel near miles 1 and 2. The eddy which usually formed off the end of East Headland was moved upstream off the end of the proposed extension, scouring a hole 109 ft deep between the deflecting dike and submerged sill. The scour hole below the sill was filled to a maximum depth of only 67 ft below mG1.

#### Plan R-1 (test 21)

81. Description. Plan R-1 (see plate 26) was a modification of plan R, and differed from the latter in that: (a) the third as well as the second left-bank dike above Pas a Loutre was extended; (b) a dredge cut was made along the proposed dikes and into Southwest Pass before

beginning the test; (c) four unprotected sand dikes were constructed along the right bank at the head of Southwest Pass; and (d) channel depths of 40 ft over a bottom width of 600 ft were maintained in the head of Southwest Pass by dredging at the end of each two years of operation.

82. Results. Plan R-1 produced the most satisfactory channel of any of the plans tested thus far (see plate 26 and photograph 4). Shoaling in the channel above Head of Passes formed a bar of less than 35-ft depth from along the right bank near Cubits Gap to about the center of the channel near Pilottown; a 40-ft channel of about 1000-ft width was obtained along the left bank. Considerable scouring occurred along the proposed dikes and extensions. Depths of more than 80 ft were obtained opposite the entrance to Pas a Loutre above the proposed dike system. Channel depths and suitable channel alignment into Southwest Pass were maintained by dredging at the ends of runs 2 and 4. Only a small amount of dredging was required at the end of run 4, and a 600-ft by 40-ft channel was maintained without dredging for the remainder of the test. Most of the material scoured from along the proposed dikes was moved into South and Southwest Passes. The large movement of material into Southwest Pass shoaled the channel below mile 1 to less than 35 ft early in the test. Most of the material forming this shoal was scoured out after the channel upstream had become stable, indicating that under stable conditions this shoal would probably disappear, but a channel of sufficient depth in this area had not been attained by the end of the test. Considerable shoaling occurred in South Pass below the head and below mile 2. A bar which formed below the extended left-bank

dikes partially blocked the entrance to Pas a Loutre. The eddy that usually forms off the end of East Headland was moved upstream off the end of the proposed extension, scouring a hole 121 ft deep between the deflecting dike and sill. The scour hole below the sill filled to a maximum depth of only 50 ft below mG1. The discharge distribution for this test was the same as for plan R (see table 6).

Plan R-2 (test 22)

83. Description. Plan R-2 (see plate 27) was similar to plan R-1 except that the two left-bank dike extensions were shortened 50 and 300 ft, respectively, and the dredge cut was shifted 200 ft to the right of that of plan R-1.

84. Results. The results of this test (plate 27) indicated that the extension of the left-bank dikes had been a definite factor in producing a satisfactory channel during the test of plan R-1. The shortening of these dike extensions in plan R-2 increased the amount of dredging and resulted in a channel of less depth than in the former test. Channel alignment and depths into Southwest Pass were maintained by dredging at the ends of runs 2, 4, 6, and 8. A 40-ft channel of about 600-ft minimum width was obtained by the end of run 10; however, by the end of the test this channel had shoaled slightly and a channel of 37-ft controlling depth and 800-ft width was obtained. The Southwest Pass channel near mile 2 was shoaled to slightly less than 40 ft. The decrease in the amount of material moved from the upstream channel caused depths through South Pass to improve over those obtained in the test of plan R-1; however, shoaling was still evident near miles 1 and 2. No material change was noted in the Pas a Loutre channel from that of the test of plan R-1.

Plan R-3 (test 23)

85. Description. Plan R-3 (see plate 28) was similar to plan R-1 except that the Pas a Loutre sill and deflecting dike were gapped and the dredge cut into Southwest Pass was made 800 ft wide instead of 600 ft.

86. Results. The results of this test (plate 28) were generally the same as those obtained in the test of plan R-1. The gap in the Pas a Loutre sill permitted more material from upstream to move into that channel at the start of the test. However, during the progress of the test, a bar which formed below the lower left-bank dike extension as in plan R-1 completely closed the gap in the deflection dike. The gap in the dike would probably have to be moved toward the East Headland extension in order to be effective; however, such a change in the location of the gap would endanger the stability of the proposed East Headland structures. The increase in the material moved into Pas a Loutre almost completely filled the scour hole below the sill. The channel into Southwest Pass was in about the same condition as in the test of plan R-1. The amount of maintenance dredging required during this test was slightly greater than in the test of plan R-1 due to the increase in the width of the maintained channel. Some improvements were noted in the depths of the South Pass and Southwest Pass channels below the heads.

Plan S (test 24)

87. Description. Plan S (see plate 29) was tested to determine the effects of the removal of the West Headland structure with no other improvements or changes in the existing structures. The test was discontinued at the end of the sixth run, before stability of the bed

was reached, when it became apparent that no improvement in channel conditions would result from the removal of the Headland structure.

88. Results. Since this test was not run to completion, the ultimate condition of the channel with the West Headland removed was not attained in the model. The results obtained during this test, however, indicated that shoaling at the Head of Passes would have a tendency to be increased rather than be diminished (plate 29). With the removal of the West Headland structure, some contraction was lost and consequently shoaling increased. With the Headland removed, the currents entering Southwest Pass would move farther toward the left, providing a satisfactory channel into South Pass at the expense of Southwest Pass. As the dredged cut along the right bank at the head of Southwest Pass shoaled, scouring at the head of South Pass increased. With the exception of the immediate vicinity, the removal of West Headland structure had no effect on the channels in the Head of Passes area or on the discharge distribution in South and Southwest Passes (see table 6).

#### Plans U, V, W, and V-1

##### Plan U (test 26)

89. Description. Plan U (see plate 30) involved the construction of 8 permeable dikes along the right bank at the head of Southwest Pass. A channel of 50-ft depth and 800-ft bottom width was dredged into Southwest Pass from along the left bank of the main river at mile 0.9 into Southwest Pass. The material from this dredging operation was spoiled between the proposed right-bank dikes. No maintenance dredging was simulated during this test.

90. Results. No appreciable change from base-test conditions was indicated in the channel above Head of Passes (see plate 30). The right-bank dikes effected some increase in channel depths from mile 1 above Head of Passes to below the entrance to Southwest Pass. By the end of the test a 35-ft channel of about 600-ft width was obtained at the entrance to Southwest Pass, but the alignment of the channel and its proximity to the West Headland structure would make navigation into the pass hazardous. Shoaling occurred along the left bank in the Southwest Pass channel near mile 2.5 closing the 40-ft channel in that vicinity. More than 40-ft central depths were obtained at the entrance to South Pass; however, a bar less than 30 ft in depth which formed just above and to the left of West Headland decreased the width of the entrance channel.

Plan V (test 27)

91. Description. Plan V (see plate 31) was designed as a modification of plan U in an attempt to produce a more satisfactory channel into Southwest Pass. Plan V included the following changes in the existing improvement works: (a) the construction of six permeable pile dikes along the right bank at the head of Southwest Pass; (b) the removal of the eight short spur dikes on the Southwest Pass side of the West Headland structure; and (c) the dredging of a channel of 800-ft bottom width and 50-ft depth from about 1 mile above the Head of Passes to 1 mile below into Southwest Pass. The material dredged was spoiled between the proposed right-bank dikes. No maintenance dredging was simulated after the start of this test.

92. Results. The results of this test (plate 31 and photograph 5)

indicated that plan V would effect a navigable channel in the head of Southwest Pass, and that no maintenance dredging would be required after sufficient high water had occurred for the bed in this vicinity to reach approximate stability. This plan had the following advantages: (a) it provided a self-maintaining channel along a smooth sailing line; (b) its installation would be relatively simple and economical; and (c) it provided a minimum of interference with the present natural tendencies of the river, having no measurable effect upon stage heights or upon discharge distribution. Possible disadvantages appeared to be some weakening of the West Headland dike by the removal of the spur dikes and slight increasing of velocities adjacent to the headland. It might be desirable, therefore, that this plan include some strengthening of the West Headland dike and the revetting of the Headland itself if such revetment does not already exist. Detailed results are given in the following subparagraphs.

- a. Channel above Head of Passes. The channel above the Head of Passes remained fairly stable during the test. Some shoaling was noted just below Cubits Gap during the early runs which slightly decreased the width of the 40-ft channel; however, by the end of the test the channel had increased to about the same dimensions as obtained in the base test. The test results indicated that plan V would have no measurable effect upon conditions in the channel above Head of Passes, and that no additional improvement works were needed in this reach.
- b. Southwest Pass. The dredged channel in the head of Southwest Pass was shoaled to less than 40-ft depths in the early runs before stability was reached. However, by the end of the 8th run, a channel of 40-ft depth and over 600-ft width was obtained which was self-maintained for the remainder of the test. At the end of the test the stabilized channel in the head of Southwest Pass had depths of over 35 ft over a minimum width of 800 ft. Some shoaling occurred toward the left side of

the channel near mile 2.5, but the 35-ft channel had a minimum width of over 600 ft and central depths of well over 40 ft.

- c. South Pass. Plan V had no appreciable effect on South Pass channel. A small bar formed across this channel immediately above the head of the pass having controlling depths of 30 ft at the end of the 10th run and 34 ft at the end of the test.
- d. Discharge distribution. The discharge distribution in South and Southwest Passes remained practically constant throughout the test, with no change from base-test conditions indicated. The installation of plan V had no measurable effect on stage heights either in the main river or in any of the passes. Model indications were that this plan would have no measurable effect upon the distribution of discharge.

#### Plan W (test 28)

93. Description. Plan W (see plate 32) was similar to plan V except that in plan W the West Headland structure was removed. Since it was believed that with plan V installed some strengthening of West Headland structure might be required and since no provisions were made in plan V for the improvement of the current alignment just below the entrance to South Pass, plan W was designed in an attempt to eliminate these undesirable conditions by the removal of the entire West Headland structure.

Plan W included: (a) the construction of six permeable pile dikes along the right bank at the head of Southwest Pass; (b) the removal of the West Headland structure to a depth of 45 ft below mGl; and (c) the dredging of a channel of 800-ft bottom width and 50-ft bottom depth from about 1 mile above Head of Passes to 1 mile below into Southwest Pass and from mile 0 for about 0.5 mile into South Pass. The spoil from the dredging operation described above was placed between the proposed right-bank dikes. No maintenance dredging was simulated after the start of the test.

94. Results. The results of the test (see plate 32) of plan W are described in detail in the following subparagraphs.

- a. Above Head of Passes. The channel above Head of Passes was not affected by the removal of the West Headland structure. Except for some increase in depths over the shoal area along the center of the channel below Cubits Gap, the channel remained fairly stable throughout the test. Test results indicated that the installation of plan W would produce no appreciable effects in this area.
- b. Southwest Pass. The dredged channel at the head of Southwest Pass shoaled to less than 40-ft controlling depths by the end of the test. Except for the point bar which formed along the right edge of the channel opposite the head of South Pass to produce a somewhat unfavorable alignment of the channel into Southwest Pass, a channel of approximately 1000-ft width and 38-ft minimum depth was obtained along the entrance channel into Southwest Pass. Shoaling occurred along the left bank just below mile 2, filling the 40-ft channel in that vicinity to a controlling depth of 38 ft.
- c. South Pass. An unstable bar formed along East Headland during this test; however, more than sufficient depths for a satisfactory entrance channel into South Pass existed to the right of this bar. No material reduction in the size of the scour hole near False Point was noted during the test.
- d. Discharge distribution. The discharge distribution in South Pass and Southwest Pass remained practically constant throughout the test, with no change from base-test conditions indicated. The installation of plan W in the model had no effect on stage heights either in the main river or in any of the passes.

#### Plan V-1 (test 29)

95. Description. Plan V-1 (see plate 33) was designed as a modification of plan V in an attempt to improve the entrance into South Pass. Plan V-1 included all of the features of plan V, plus the removal of False Point at the head of South Pass. The dredged material in both plans was spoiled between the proposed right-bank dikes. No maintenance dredging was simulated after the start of either test.

96. Results. The results of plan V-1 (see plate 33 and photograph 6) were similar to those of plan V (described in paragraph 92) except at the head of South Pass. The removal of False Point increased the channel width and cross-sectional area in that vicinity and caused considerable shoaling to occur along the West Headland indicating that removal of this point would not effect the desired channel improvement. The eddy caused by False Point was eliminated; however, no change was noted in the deep scour hole.

## PART VI: DISCUSSION OF RESULTS

Interpretation of Model Results

97. The interpretation of results of the model study, and the reliance to be placed thereon, are based chiefly on the verification of the model. The principle of verification is based upon the premise that proof of the ability of the model to reproduce accurately events that are known to have occurred in the prototype constitutes proof of its ability to reproduce accurately events that will occur as a result of future similar operations.

98. In the interpretation and evaluation of the results of the model tests of the various improvement plans in the Head of Passes area, it should be kept in mind that the results of the model tests are inherently of a qualitative nature, and cannot be given a strictly quantitative interpretation. The model tests are considered representative of normal prototype occurrences and cannot be expected to indicate the results of prolonged periods of unusually high or low flows. It must also be considered that in tests conducted on the Head of Passes model, it was assumed that the dredge cut in Southwest Pass from about mile 10.5 to the Gulf was completed and maintained for the duration of all tests. The effects of this dredge cut maintained in its original condition, and the fact that this may not actually be the case in the prototype, must be kept in mind when interpreting the results of the model tests. However, the model results are considered to provide an excellent indication of the relative effectiveness of the various improvement plans, and a reasonably close approximation of the results

to be expected in the prototype under normal conditions.

#### Summary of Results

99. The results of the Head of Passes model study indicated that plan H, recommended by the Board of Officers (see paragraph 11) and tentatively approved for construction in the prototype, would not produce the desired channel improvements in the Head of Passes area. Plan H involved the dredging of a deep channel from Cubits Gap to below the head of Southwest Pass along the right bank and the construction of fills along the left bank below Cubits Gap and along the West Headland from this dredge spoil. This plan was ineffective since the unprotected fills were scoured and the dredged channel was filled after a short period of operation. The model study indicated that the features of plan H as tested in the model would soon be destroyed by scouring and shoaling action, and that the ultimate conditions of the channel would be essentially the same as if no improvement works had been constructed.

100. The plan recommended by the Board of Officers was modified in plan I to include larger fills along the left bank below Cubits Gap and along the West Headland structure with the dredge cut being the same as in plan H. The fills of this plan were protected from erosion with simulated mats. This plan produced a considerable increase in the depths of the channel above Head of Passes and reduced the shoaling in the entrance to Southwest Pass. However, a satisfactory channel into Southwest Pass was not obtained; this and other undesirable conditions made the plan unfavorable.

101. The principal results of the model study are summarized

in tables 6 to 8 and in the subparagraphs which follow:

- a. The shoal area in the prototype along the center of the channel below Cubits Gap, as shown by the 1940 and 1941 prototype surveys, was probably the result of an abnormal amount of material moved into this area, and under normal conditions project depths would be maintained.
- b. Under existing conditions any dredge cut made along the right bank at the entrance to Southwest Pass would eventually be completely filled unless maintained by dredging.
- c. The channel along the Southwest Pass entrance range would shoal to less than project depth (35 ft below mG1) under average conditions of flow were it not maintained by periodic dredging.
- d. The deep scour hole just below the Pas a Loutre submerged sill was principally the result of the eddy which formed off the end of the East Headland dike. Removing short sections of the deflecting dike and submerged sill would have a tendency to increase the amount of material moved into that pass but would not affect materially the depth of the scour hole.
- e. Plans which included contraction works only along the West Headland structure would reduce shoaling adjacent to the Headland and produce local scouring in the channel but would not effect a project channel along the entrance into Southwest Pass.
- f. The removal of the West Headland structure would have a tendency to increase the shoaling at the head of Southwest Pass with no appreciable effect on discharge distribution or upon the channel downstream.
- g. The removal of False Point near the head of South Pass would considerably improve the alignment of currents and eliminate the hazard to navigation during high water; however, the removal of False Point would have a tendency to shoal the South Pass channel along the West Headland structure since the channel width would be increased.
- h. The contraction of the channel above Head of Passes by construction of dikes or fills along the left bank (below Cubits Gap) would increase the depth of the channel in that vicinity but would not affect materially the distribution of discharge in the three passes or channel conditions at the Head of Passes.

- i. Two of the 27 proposed improvement plans appeared to offer a solution to the problem at Head of Passes. One of these plans was plan R-1 (described in paragraph 81). This plan produced in Southwest Pass a 35-ft channel approximately 900 ft wide having within it a 40-ft channel 800 ft wide. The other plan that produced favorable results was plan V (described in paragraph 91). Plan V produced in Southwest Pass a 35-ft channel 900 ft wide having within it a 40-ft channel 600 ft wide. The results of these two plans are shown on plates 26 and 31, respectively. Additional tests of plans R-1 and V, under more drastic flow conditions, are described in an appendix to this report.

## **TABLES**

Table 1

PROTOTYPE DISCHARGE DISTRIBUTION AT HEAD OF PASSES

1937 Observations

Stage in Ft on Carrollton Gage	Per Cent of Total Discharge at Head of Passes		
	Pas a Loutre	South Pass	Southwest Pass
6.20	45.00	14.34	40.66
7.58	45.86	16.03	38.11
9.11	44.74	18.31	36.95
10.36	45.86	21.61	32.53
9.55	43.15	17.62	39.23
17.20	44.11	16.46	39.43
13.33	44.14	19.28	36.58
11.98	35.66	14.53	49.81
11.15	42.16	17.67	40.17
15.52	41.10	17.67	41.22
18.97	42.14	18.91	38.95
17.60	40.75	18.69	40.56
18.90	42.41	18.10	39.49
Average	42.85	17.63	39.52

Table 2

MODEL DISCHARGE DISTRIBUTION AT HEAD OF PASSES

1937 Conditions in Model

Stage in Ft on Carrollton Gage	Per Cent of Total Discharge at Head of Passes		
	Pas a Loutre	South Pass	Southwest Pass
12	43.6	15.1	41.3
13.5	43.0	17.2	39.8
15	42.9	17.6	39.5
16	42.2	18.4	39.4
17	43.2	17.9	38.9
—	—	—	—
Average	43.0	17.2	39.8

Table 3

PROTOTYPE DISCHARGE DISTRIBUTION AT HEAD OF PASSES1940 Observations

(Without Dredged Cut in Southwest Pass)

Stage in Ft on Carrollton Gage	Per Cent of Total Discharge at Head of Passes		
	Pas a Loutre	South Pass	Southwest Pass
4.02	46.07	17.83	36.10
5.15	50.16	14.62	35.22
6.94	44.39	18.23	37.38
4.72	47.59	15.34	37.07
6.12	47.15	15.30	37.55
8.19	45.43	17.83	36.74
10.47	45.46	18.46	36.08
13.57	46.02	18.92	35.06
13.06	46.77	17.53	35.88
-----	45.90	19.46	34.64
9.31	45.46	16.83	37.71
1940 Average	46.40	17.29	36.31
1937* Average	42.85	17.63	39.52
1937 to 1940 Average Change	Increased 3.55	Decreased 0.34	Decreased 3.21

\* From table 1.

Table 4

MODEL DISCHARGE DISTRIBUTION AT HEAD OF PASSES1940 Conditions in Model

(Without Dredged Cut in Southwest Pass)

Stage in Ft on Carrollton Gage	Per Cent of Total Discharge at Head of Passes		
	Pas a Loutre	South Pass	Southwest Pass
12	46.4	15.2	38.4
13.5	46.2	16.6	37.2
15	46.0	17.4	36.6
16	46.4	17.5	36.1
17	46.8	17.6	35.6
1940 Average	46.3	16.9	36.8
1937* Average	43.0	17.2	39.8
1937 to 1940 Average Change	Increased 3.3	Decreased 0.3	Decreased 3.0

\* From table 2.

Table 5

MODEL DISCHARGE DISTRIBUTION AT HEAD OF PASSES

1940 Conditions in Model

(With Proposed Dredged Cut from Mile 10.5, Southwest Pass, to the Gulf Completed to 400-ft Width and 50-ft Depth)

Stage in Ft on Carrollton Gage	Per Cent of Total Discharge at Head of Passes		
	Pas a Loutre	South Pass	Southwest Pass
12	44.2	15.0	40.8
13.5	44.4	16.0	39.6
15	45.6	16.4	38.0
16	45.6	16.6	37.8
17	45.3	16.7	38.0
—	—	—	—
1940 Average With Dredged Cut	45.0	16.1	38.9
1940* Average Without Dredged Cut	46.3	16.9	36.8
Effect of Dredged Cut	Decreased 1.3	Decreased 0.8	Increased 2.1

\* From table 4.

Table 6

DISCHARGE DISTRIBUTION DURING TESTS OF IMPROVEMENT PLANS

Test No.	Plan	Per Cent of Total Discharge at Head of Passes		
		Pas a Loutre	South Pass	Southwest Pass
2	Base Plan	44.0	17.2	38.8
3	A	44.0	17.0	39.0
4	B	44.0	17.3	38.7
5	C	44.0	17.4	38.6
6	D	44.0	17.1	38.9
7	E	44.0	16.9	39.1
8	F	44.0	17.1	38.9
9	G	44.0	17.2	38.8
10	H	44.0	16.8	39.2
11	I	44.0	16.8	39.2
12	J	44.0	17.4	38.6
13	K	44.0	17.4	38.6
14	L	44.0	17.4	38.6
15	M	44.0	17.5	38.5
16	N	44.0	17.5	38.5
17	P	44.0	17.4	38.6
18	O	44.0	16.7	39.3
19	Q	44.0	16.4	39.6
20	R	42.7	17.0	40.3
21	R-1	42.7	17.1	40.2
22	R-2	42.8	17.1	40.1
23	R-3	42.7	17.2	40.1
24	S	44.0	16.6	39.4
25	T	44.0	16.5	39.5
26	U	44.0	17.2	38.8
27	V	44.0	17.2	38.8
28	W	44.0	17.5	38.5
29	V-1	44.0	17.2	38.8

Table 7

## DREDGED QUANTITIES AND DIKE CONSTRUCTION DURING TESTS OF PROPOSED PLANS

Test No.	Initial Dredge Cut			Maintenance Dredging			Total Dredging In 1,000 Cu Yd	Proposed Dikes Constructed Linear Ft
	Plan	Dimensions	Amount In 1,000 Cu Yd	No. of Cuts	Dimensions	Amount In 1,000 Cu Yd	Average In 1,000 Cu Yd	
3	A	400 x 60	6,945	-				6,945
4	B	400 x 60	6,598	-				6,598
5	C	400 x 60	6,598	-		-	-	6,598
6	D	400 x 60	6,084	-		-	-	6,084
7	E	400 x 60	7,292	-		-	-	7,292
8	F	400 x 60	6,945	-		-	-	6,945
9	G	400 x 60	6,250	-		-	-	6,250
10	H	400 x 60	13,196	-		-	-	13,196
11	I	400 x 60	14,751	-		-	-	14,751
12	J	-	-	-		-	-	-
13	K	-	-	-		-	-	-
14	L	-	-	-		-	-	-
15	M	-	-	-		-	-	1,930
16	N	-	-	4	600 x 35	931	233	931
17	P	-	-	6	600 x 35	1,431	238	1,431
18	O	-	-	-	-	-	-	3,550
19	Q	-	-	4	600 x 40	1,667	417	1,667
20	R	-	-	-	-	-	-	5,600
21	R-1	600 x 50	1,726	2	600 x 40	69	35	1,795
22	R-2	600 x 50	1,597	4	600 x 40	431	108	2,028
23	R-3	800 x 50	2,986	3	800 x 40	306	102	3,292
24	S	-	-	-	-	-	-	-
25	T	400 x 60	11,418	3	400 x 60	13,348	4,449	24,766
26	U	800 x 50	4,167	-		-	-	4,167
27	V	800 x 50	2,778	-		-	-	2,778
28	W	800 x 50	4,348	-		-	-	4,348
29	V-1	800 x 50	2,986	-		-	-	2,986

Table 8

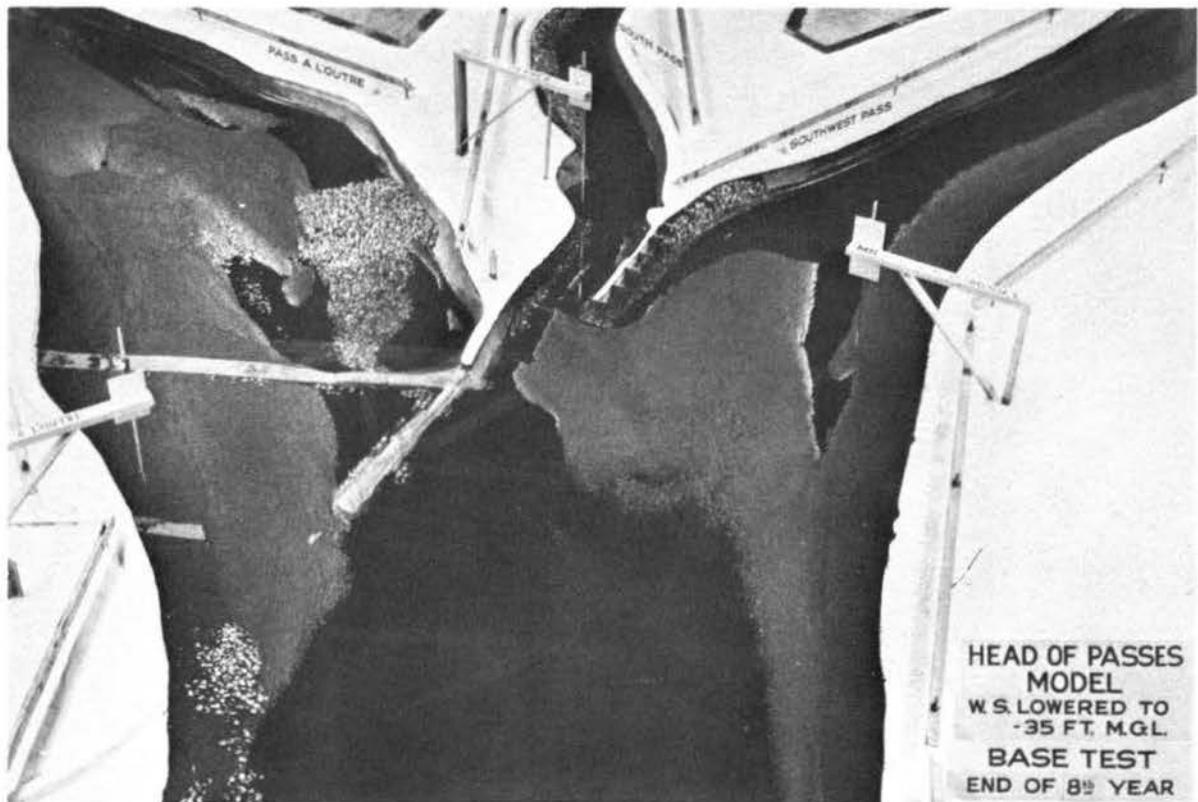
EFFECTS OF IMPROVEMENT PLANSEntrance Channel, Southwest Pass

Test	Plan	Controlling Depth in Ft Below mG1	Minimum Width in Feet	
			35-ft Channel	40-ft Channel
2	Base	29	---	---
3	A	36	300	---
4	B	32	---	---
5	C*	39	500	---
6	D	33	---	---
7	E	34	---	---
8	F	36	400	---
9	G	36	400	---
10	H	35	200	---
11	I	36	200	---
12	J	42	400	200
13	K	41	500	200
14	L	34	---	---
15	M	39	500	---
16	N	41	600	200
17	P	46	400	300
18	O	34	---	---
19	Q	35	400	---
20	R	37	900	---
21	R-1	48	900	800
22	R-2	41	800	200
23	R-3	57	900	600
24	S*	31	---	---
25	T	34	---	---
26	U	37	600	---
27	V	45	800	700
28	W	38	700	---
29	V-1	43	900	800

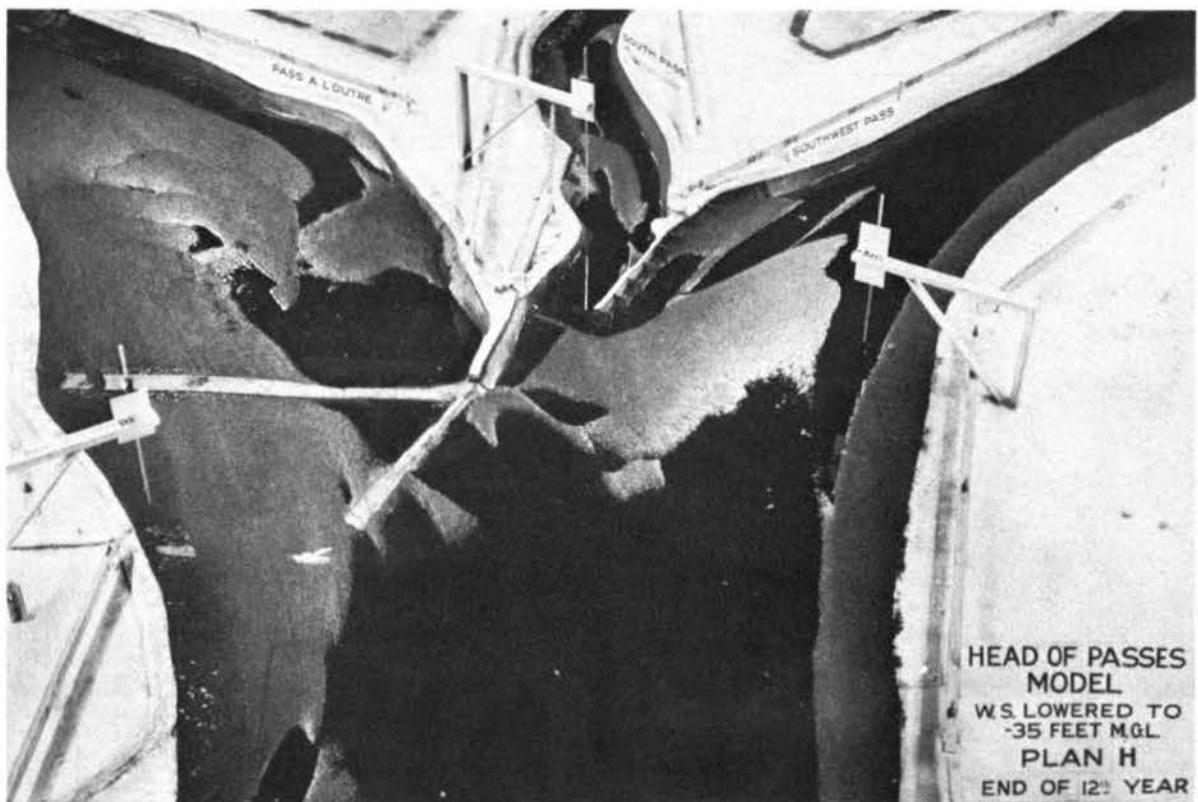
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\* Test discontinued before completion.

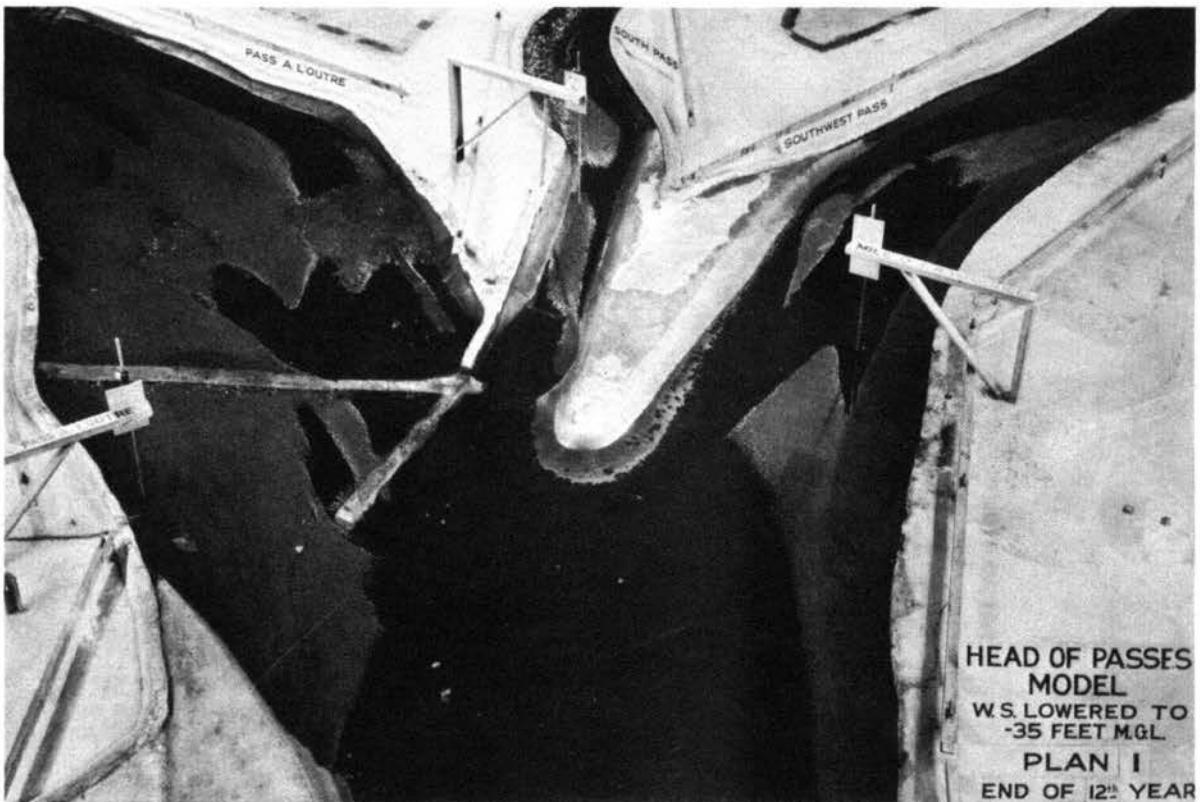
## **PHOTOGRAPHS**



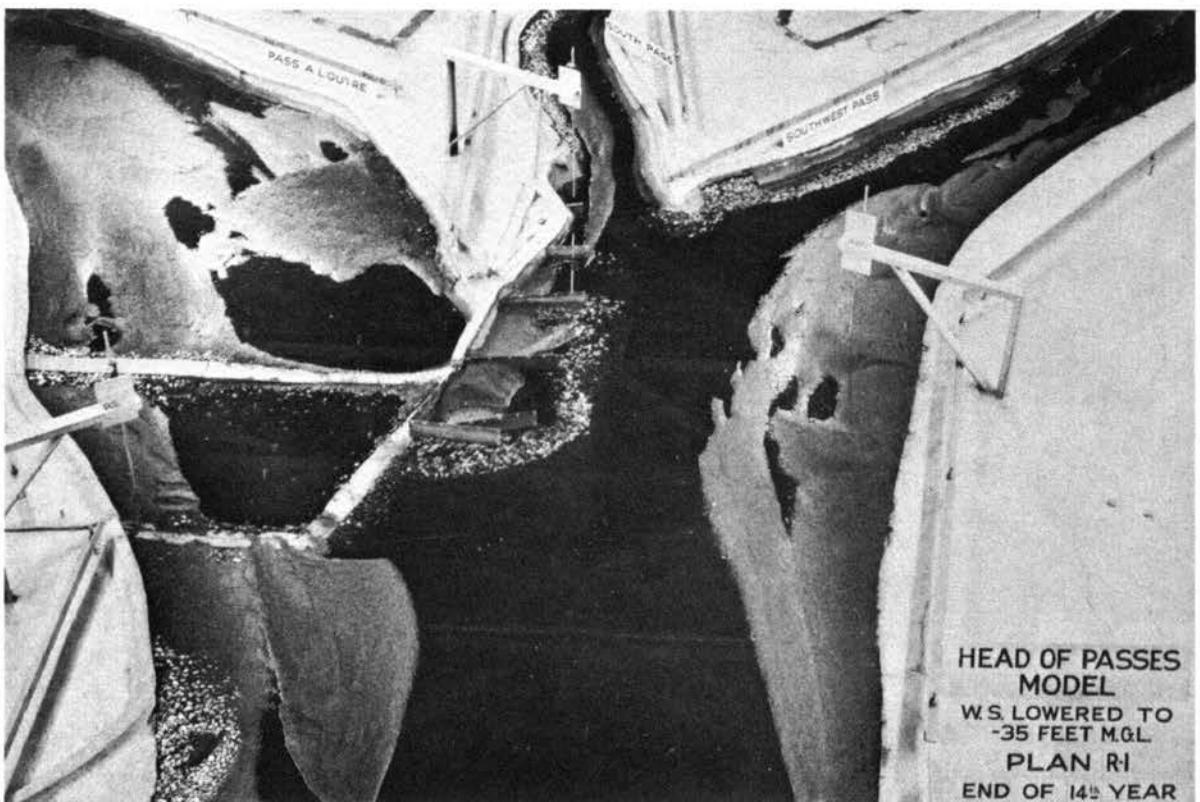
Photograph 1. Base test; test 2; end of test. Downstream view of model bed at Head of Passes. Note shoal area at head of Southwest Pass



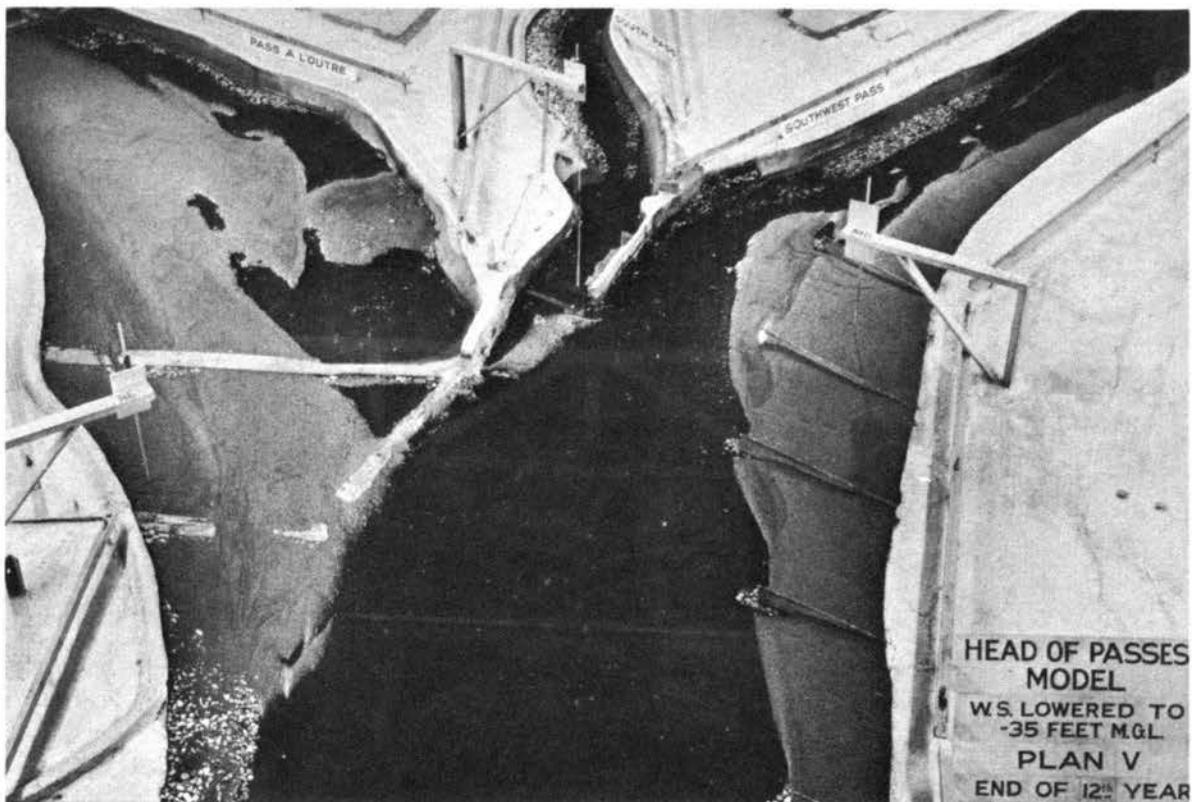
Photograph 2. Plan H; test 10; end of test. Downstream view of model bed at Head of Passes. Note shoal area at the entrance of South and Southwest Passes



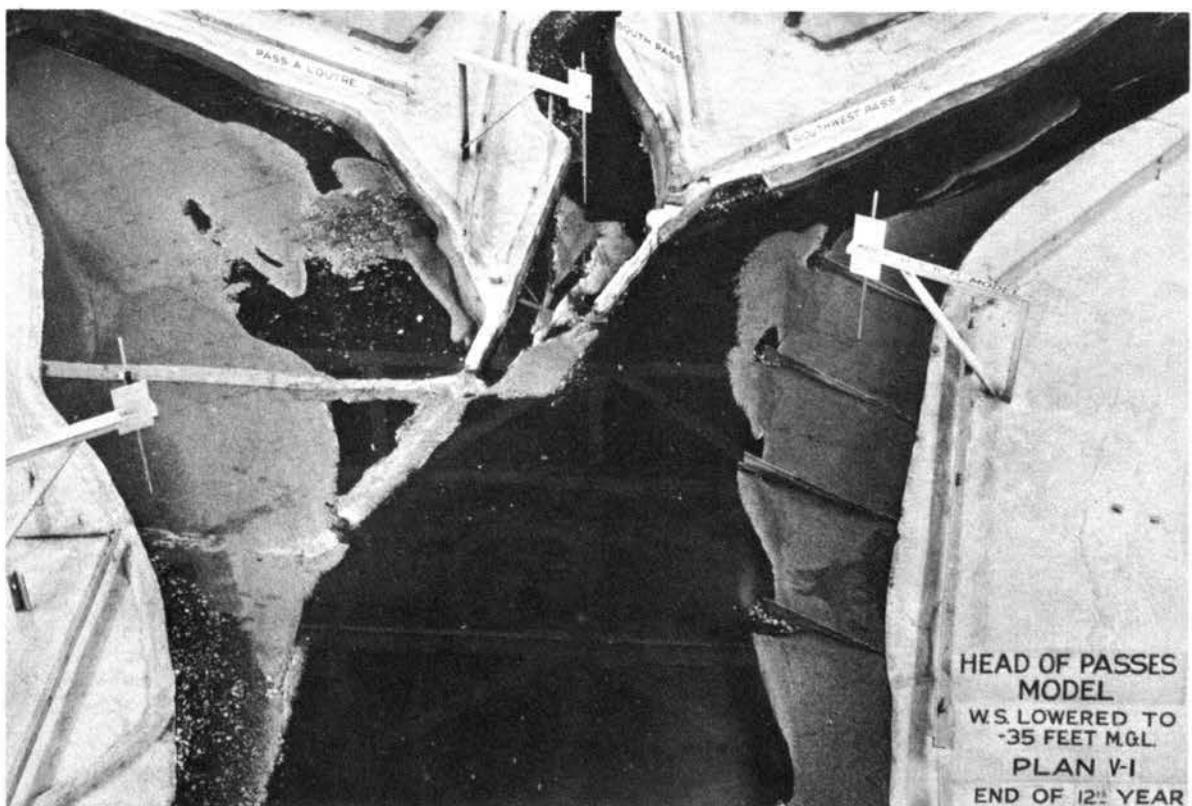
Photograph 3. Plan I; test 11; end of test. Downstream view of model bed at Head of Passes. Note split channel in Southwest Pass and shoal area at entrance of South Pass



Photograph 4. Plan R-1; test 21; end of test. Downstream view of model bed at Head of Passes. Note channel alignment into South and Southwest Passes

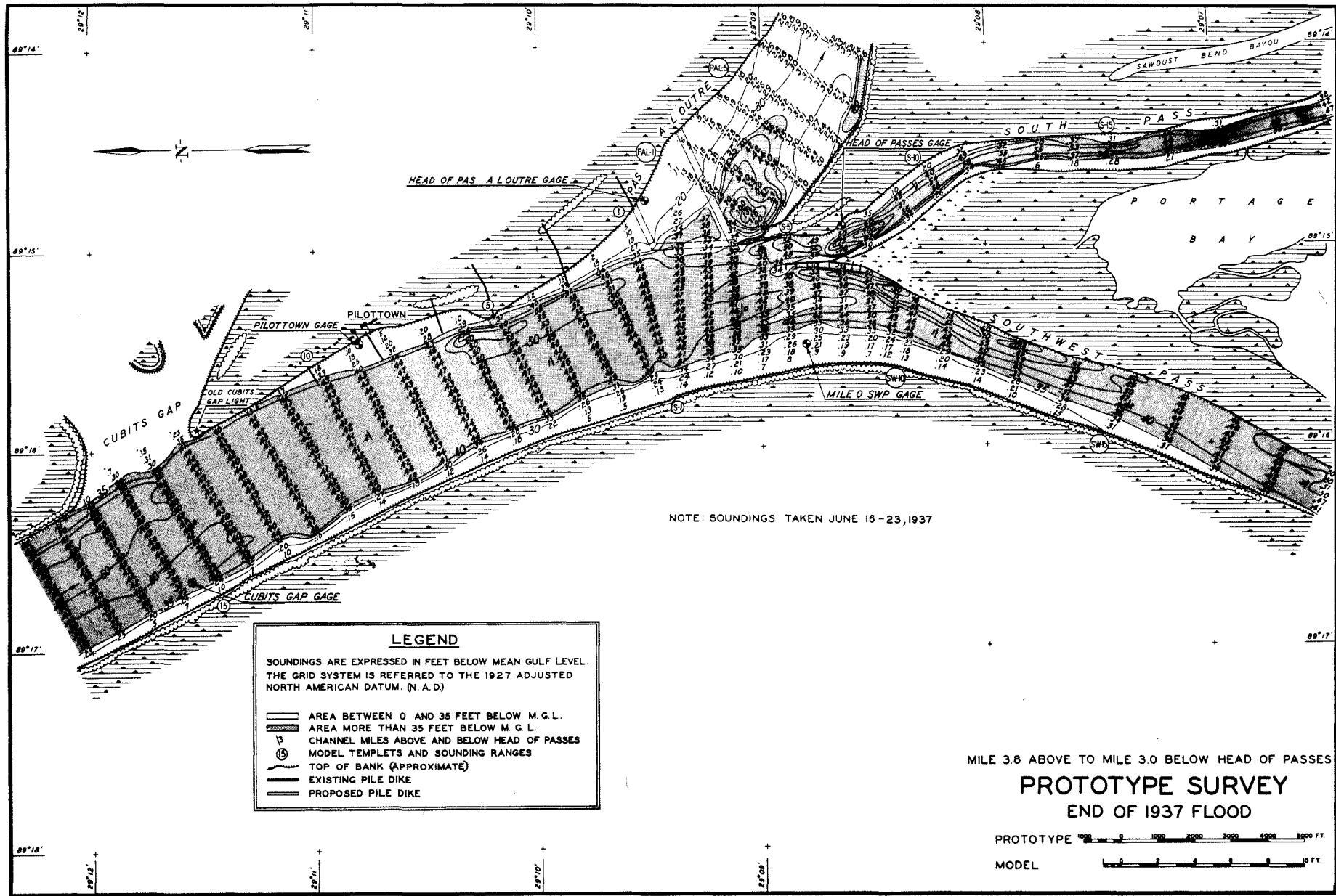


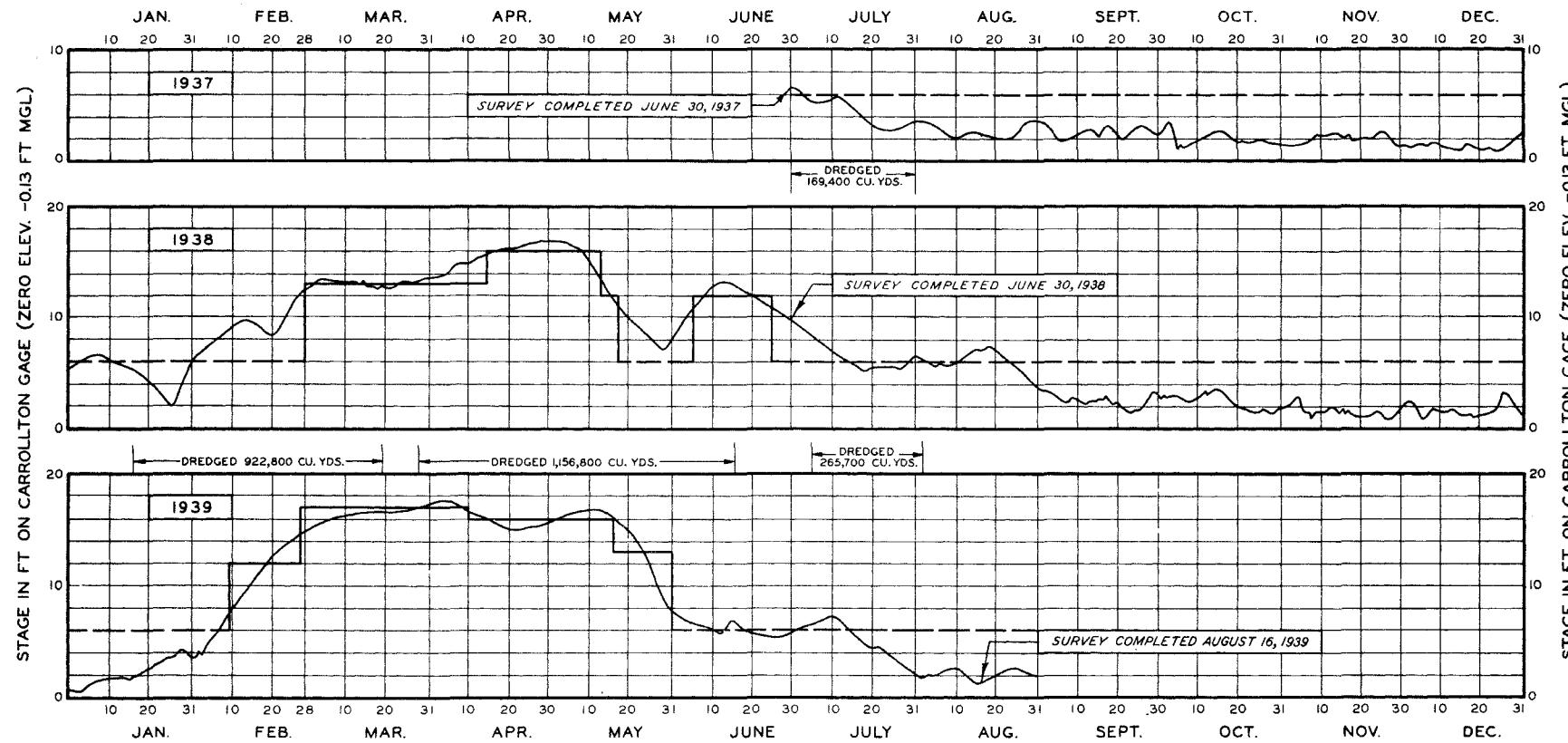
Photograph 5. Plan V; test 27; end of test. Downstream view of model bed at Head of Passes. Note channel alignment into Southwest Pass



Photograph 6. Plan V-1; test 29; end of test. Downstream view of model bed at Head of Passes. Note channel alignment into Southwest Pass and shoaling condition at head of South Pass

## PLATES

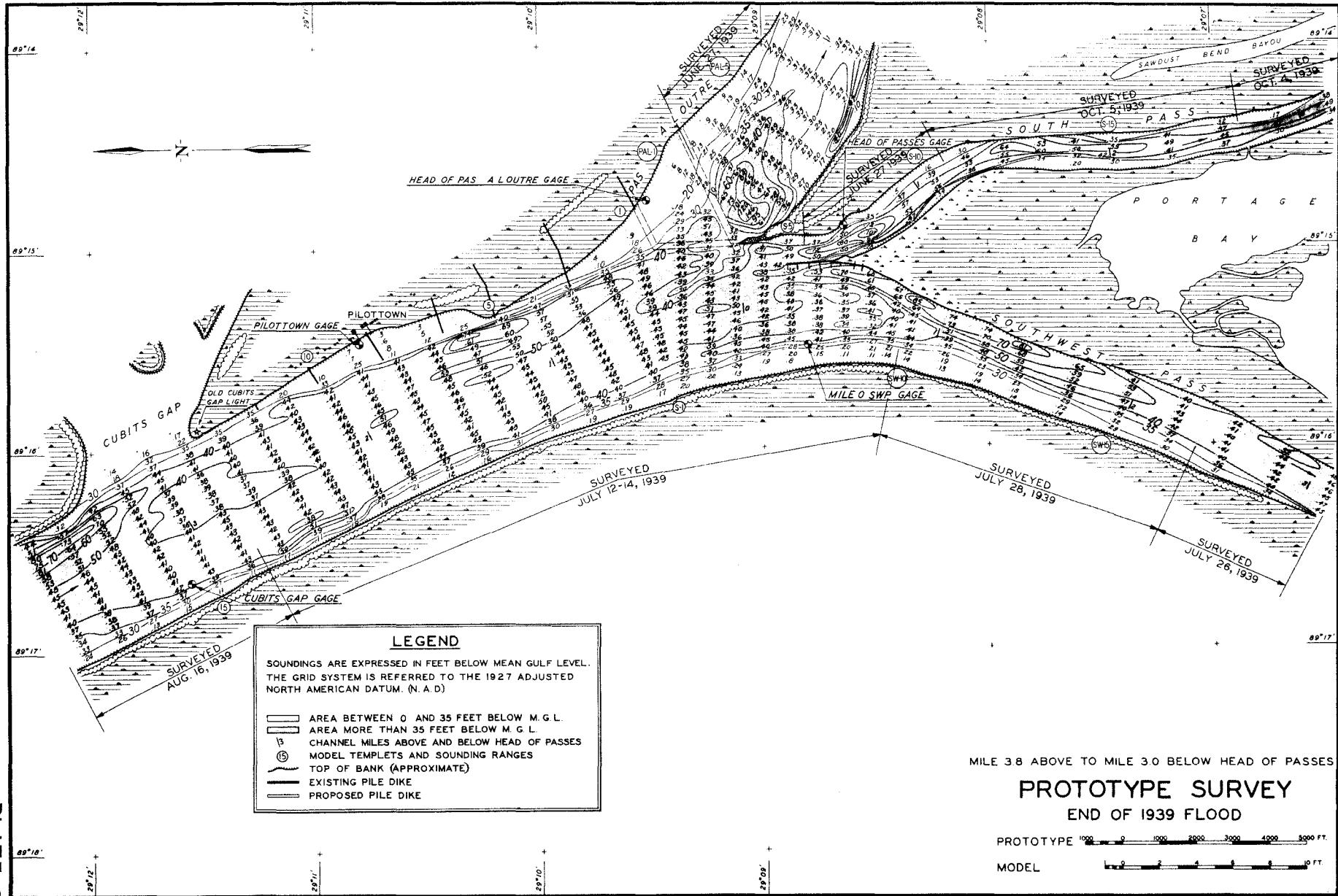


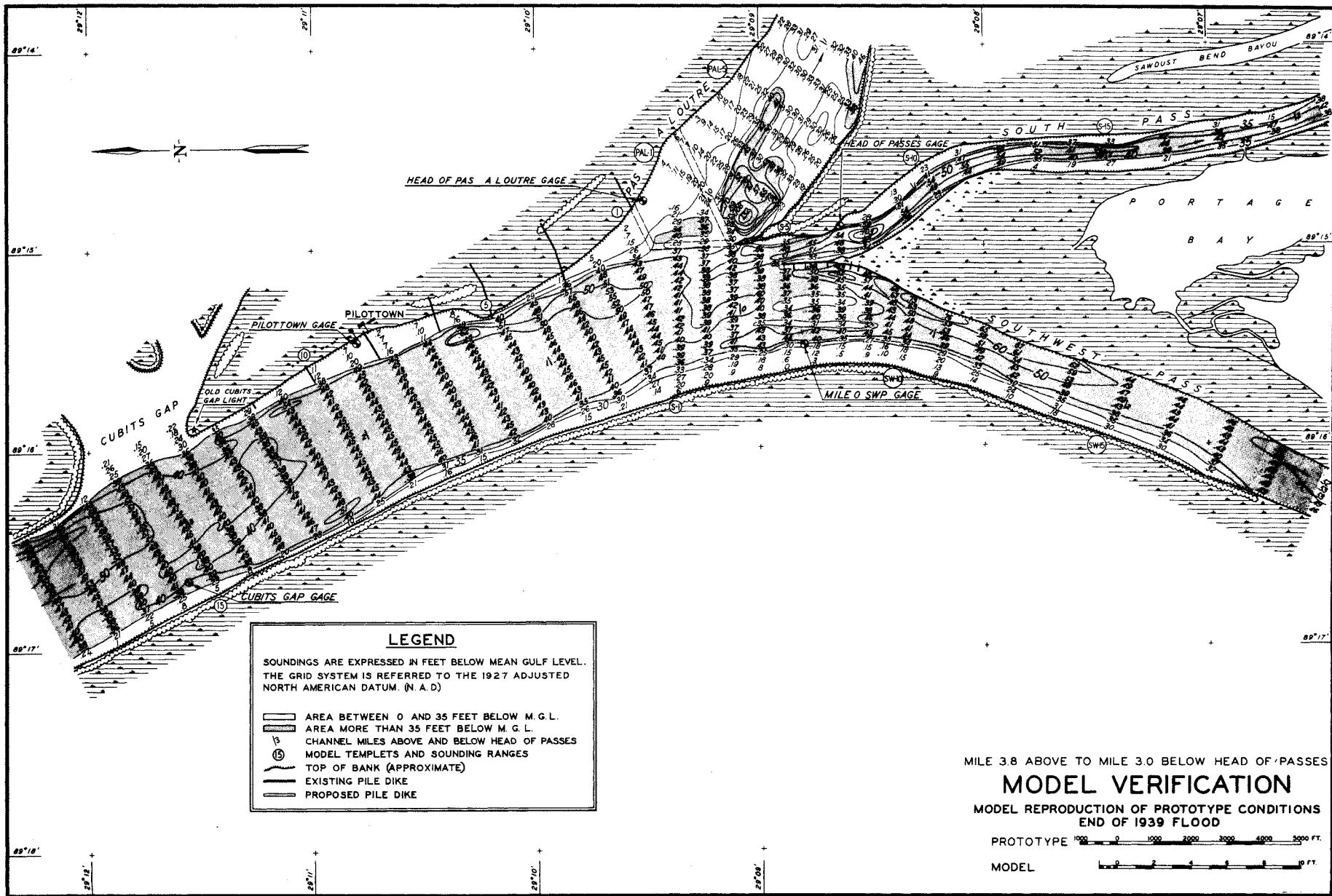
LEGEND

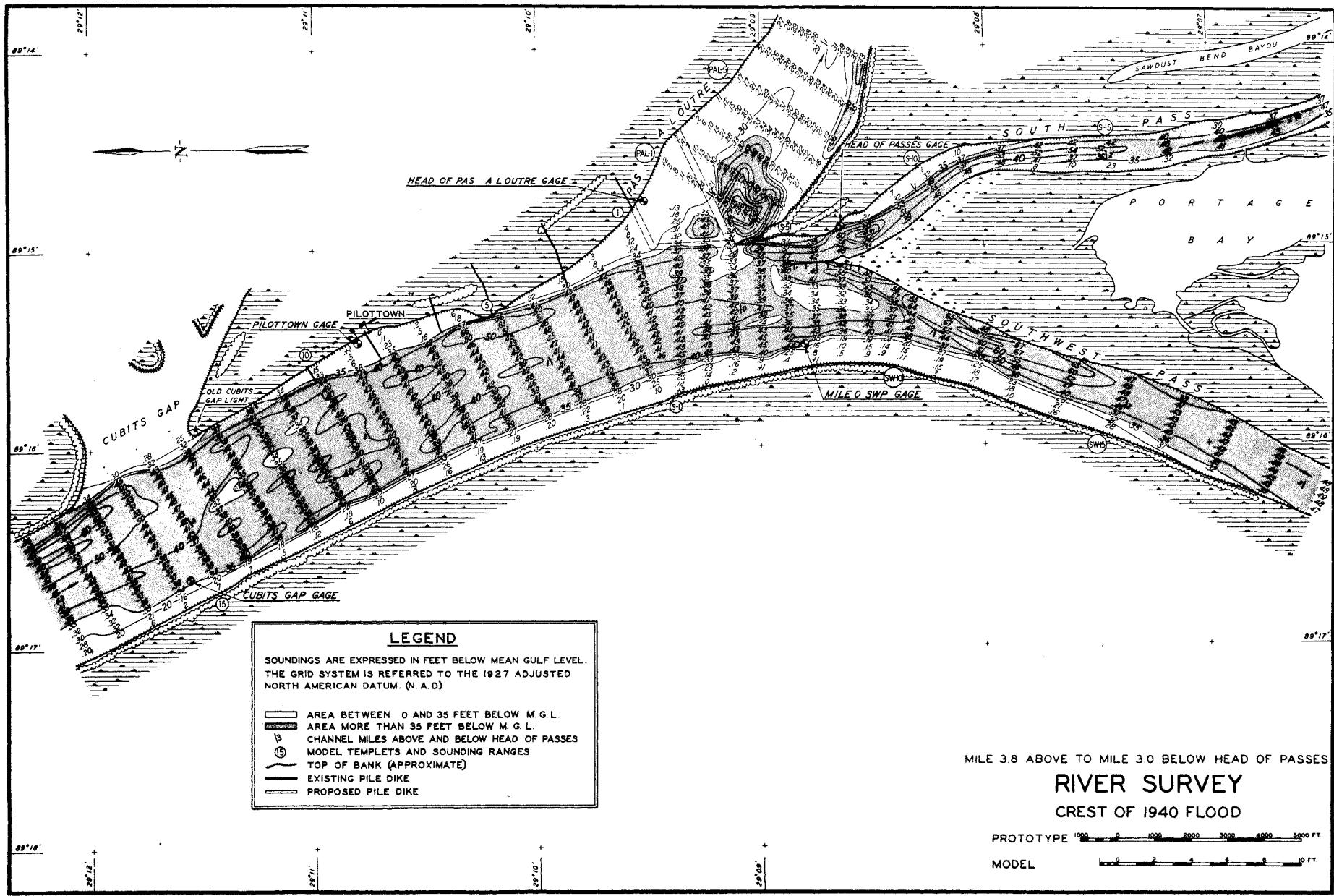
- wavy line — PROTOTYPE HYDROGRAPH
- step line — MODEL HYDROGRAPH
- dashed line — OMITTED IN MODEL OPERATION

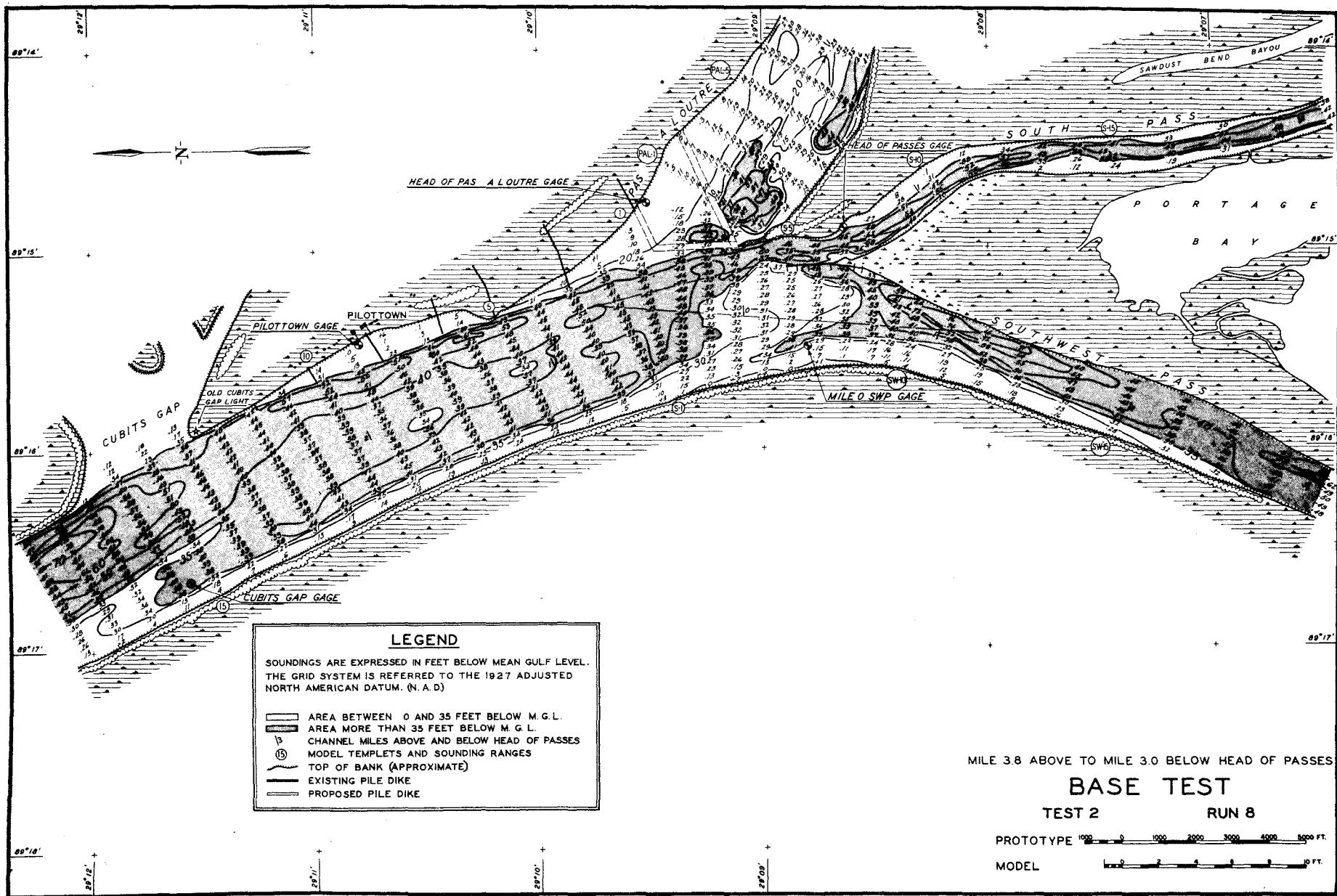
MILE 3.8 ABOVE TO MILE 3.0 BELOW HEAD OF PASSES

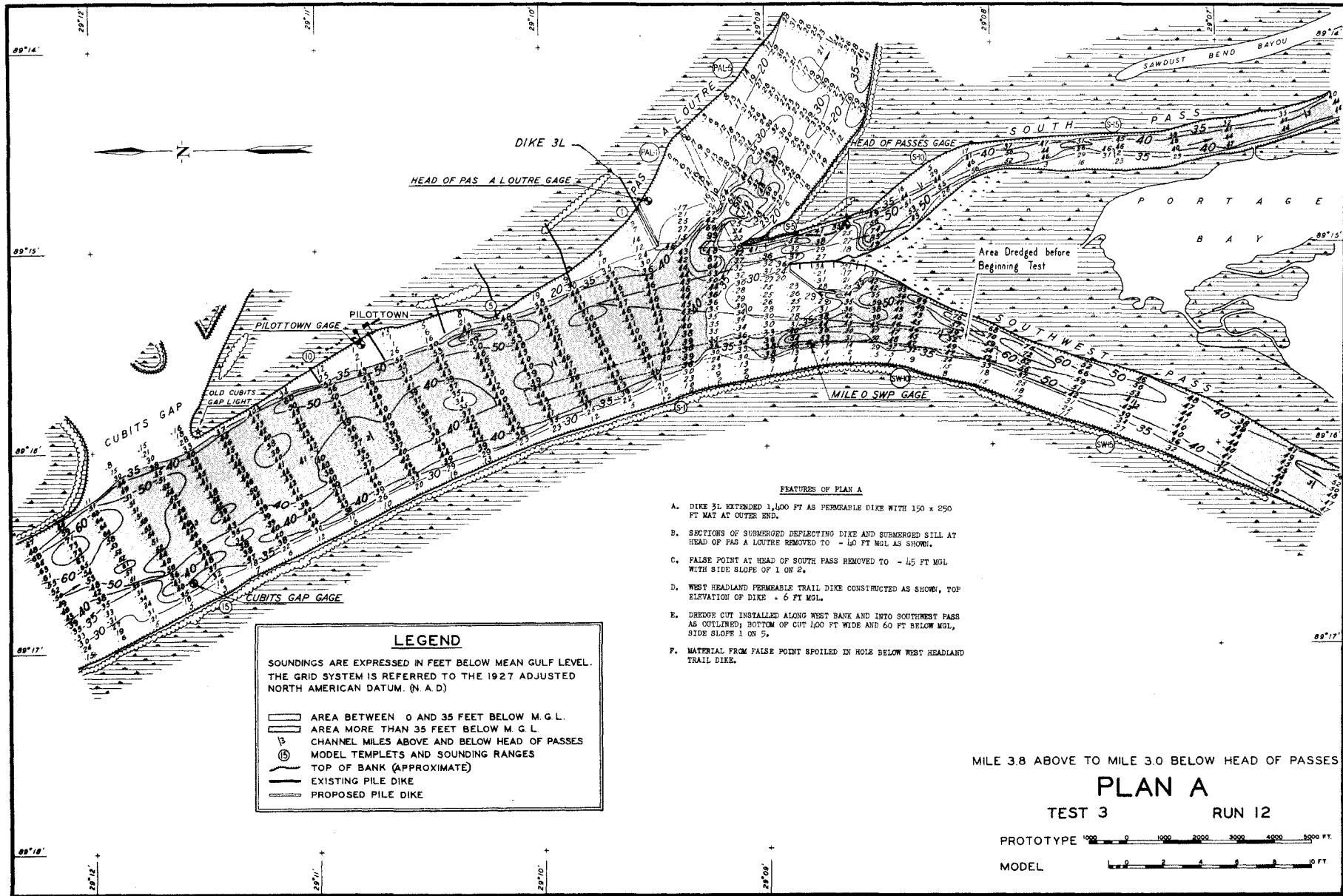
VERIFICATION HYDROGRAPH

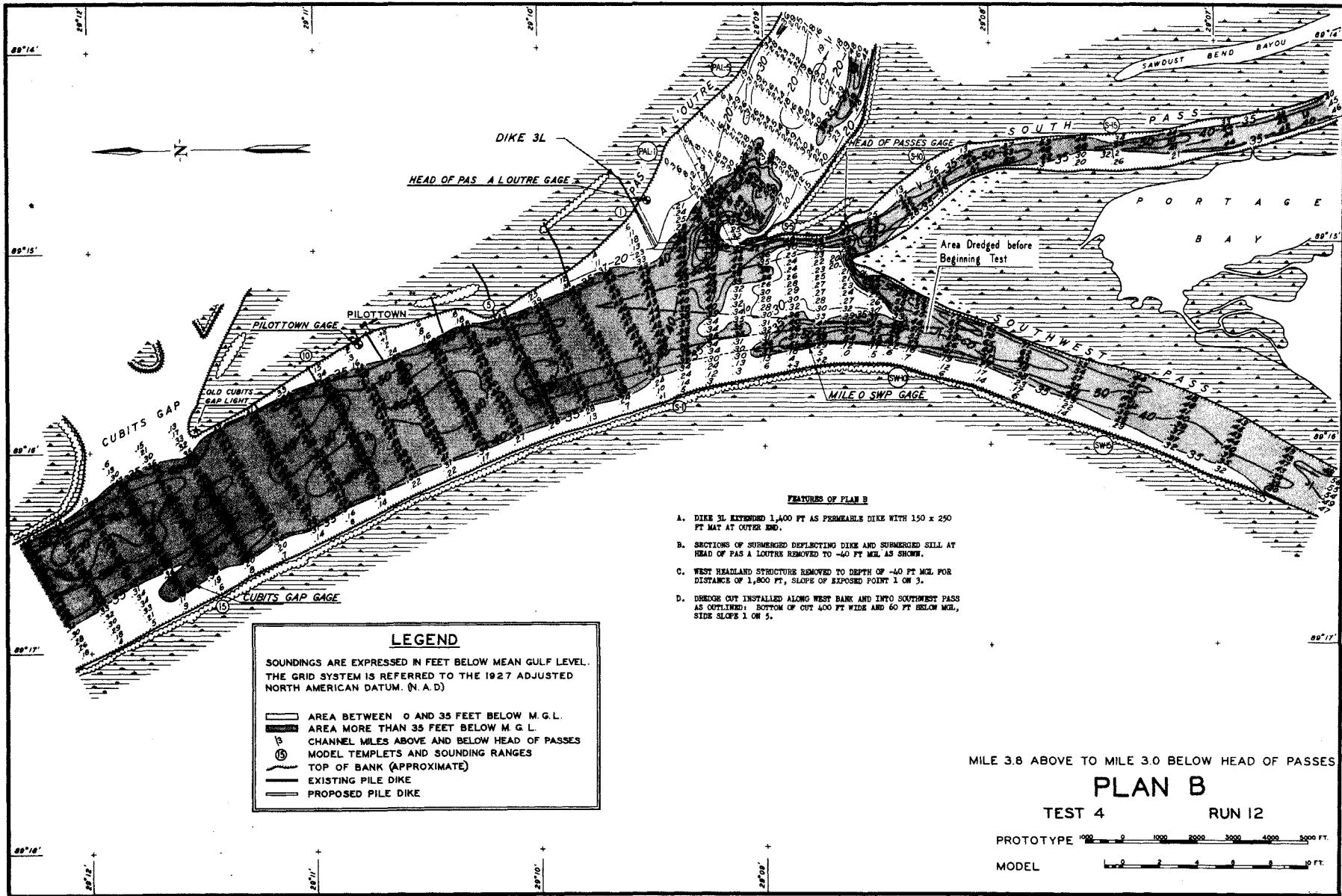


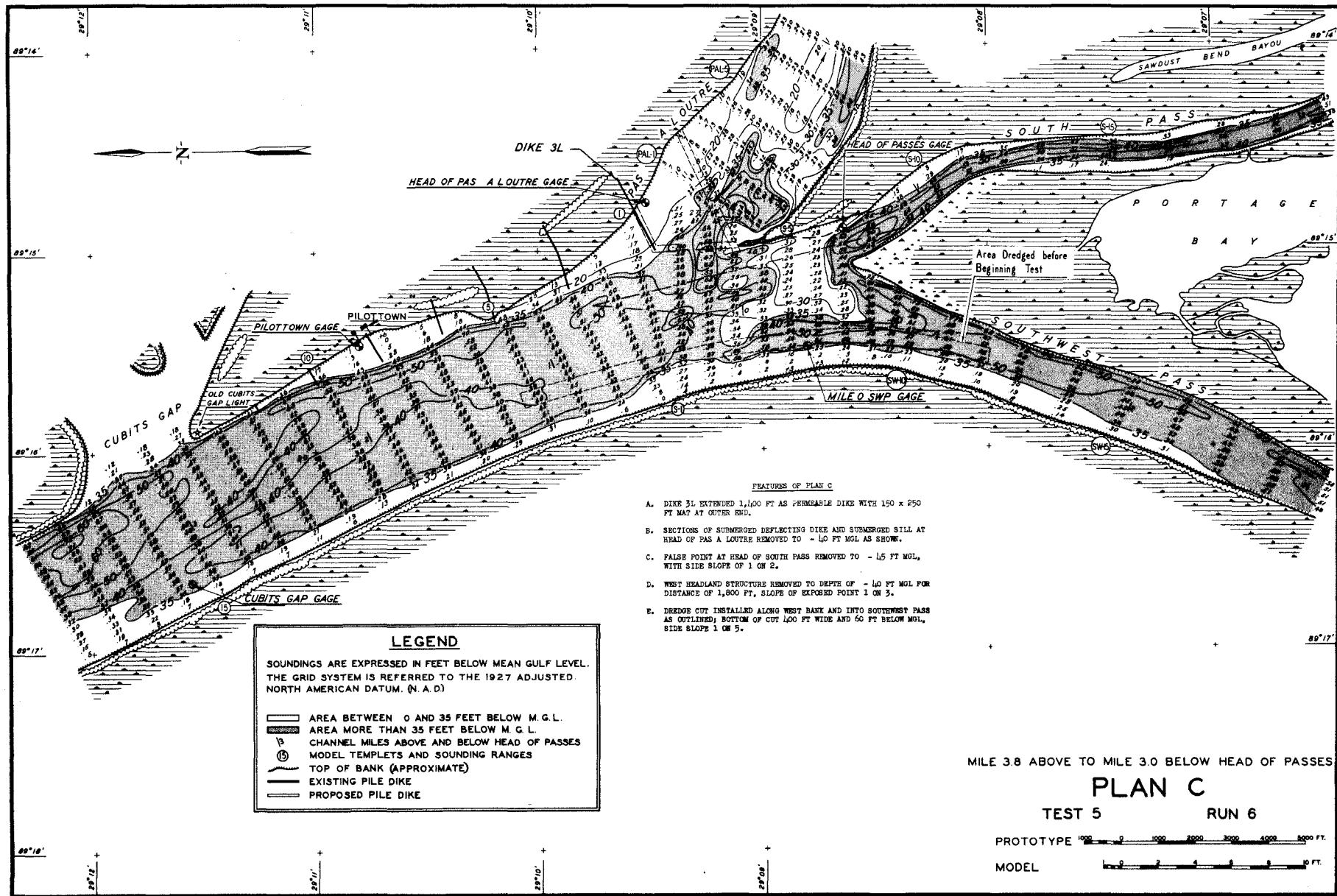


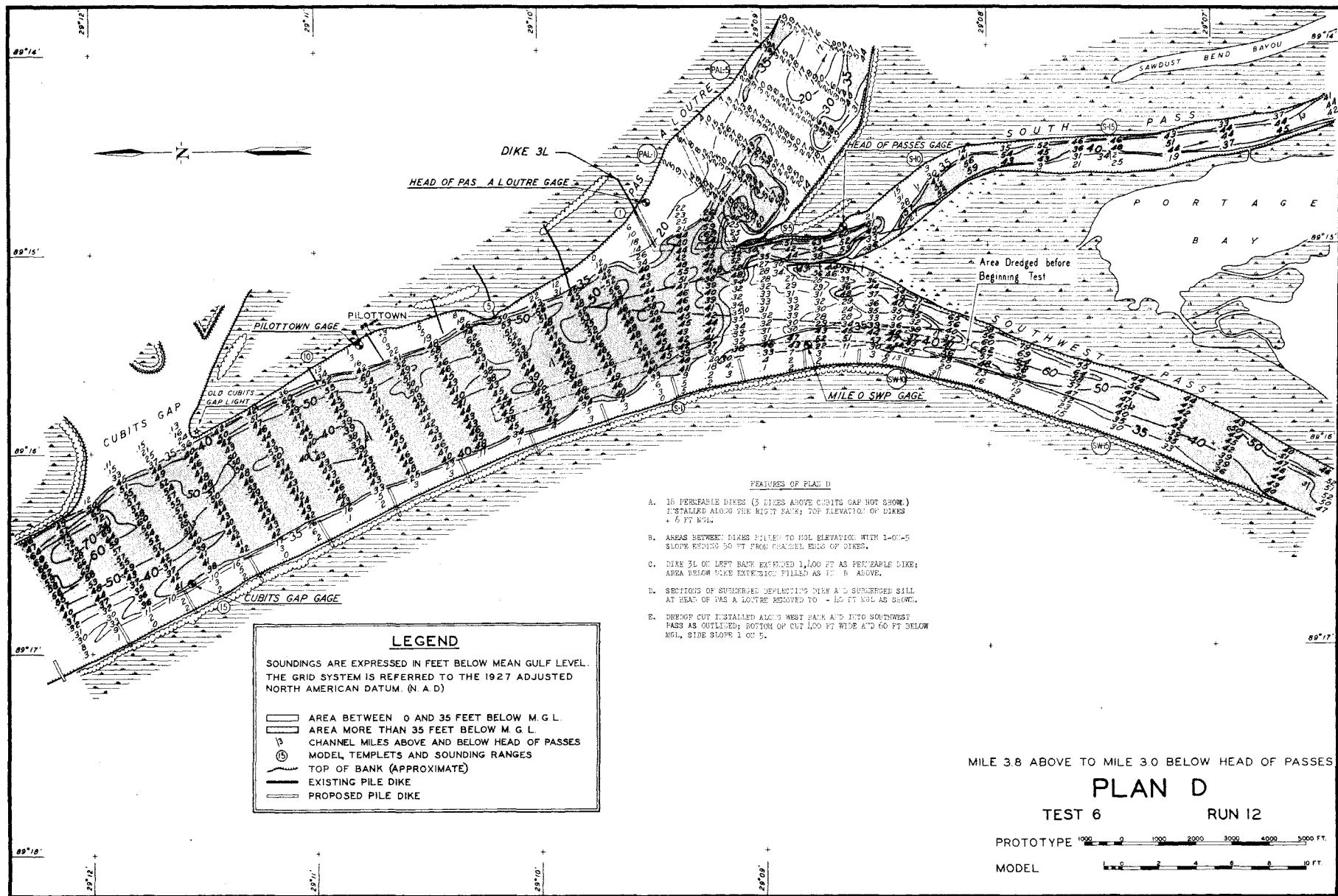


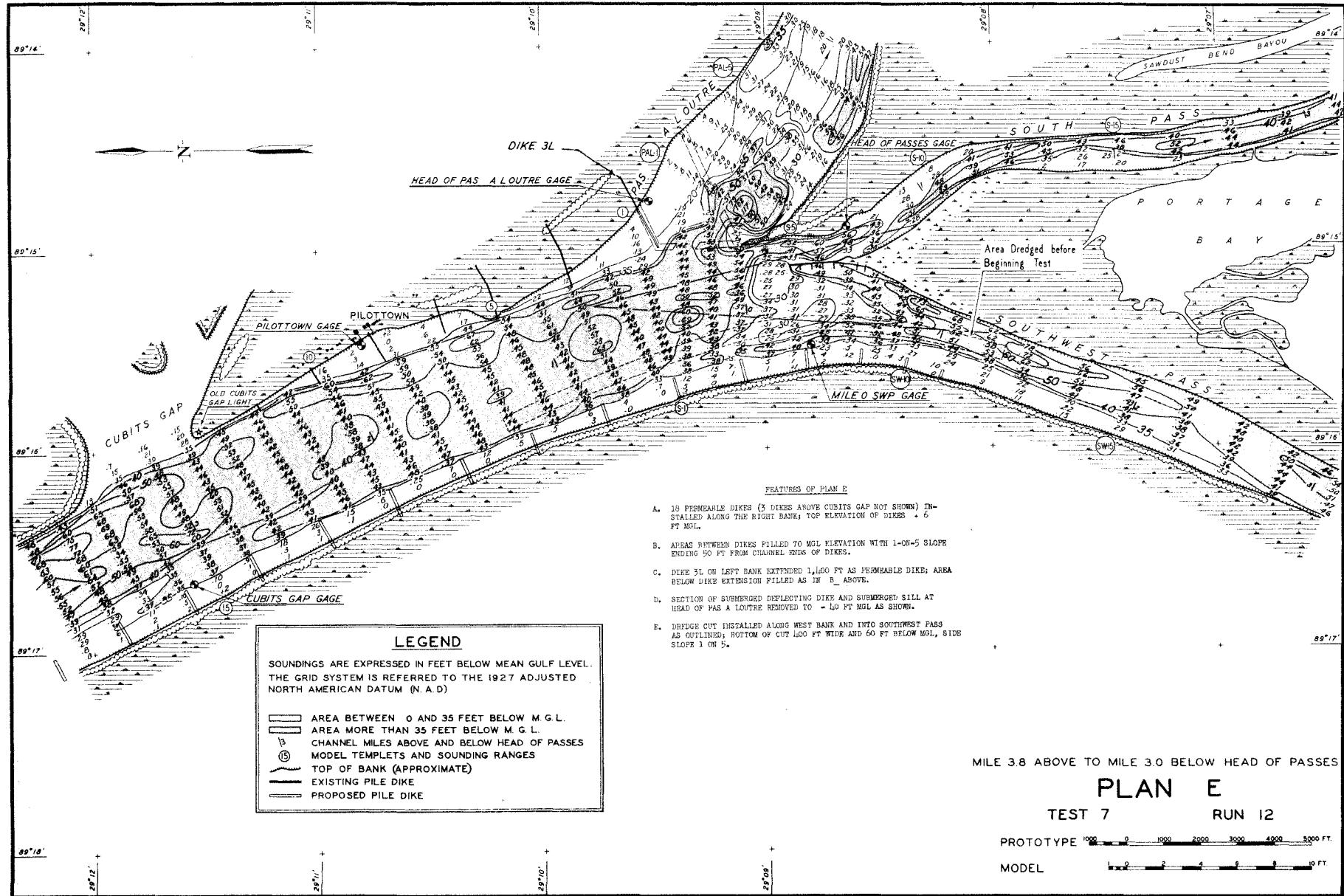


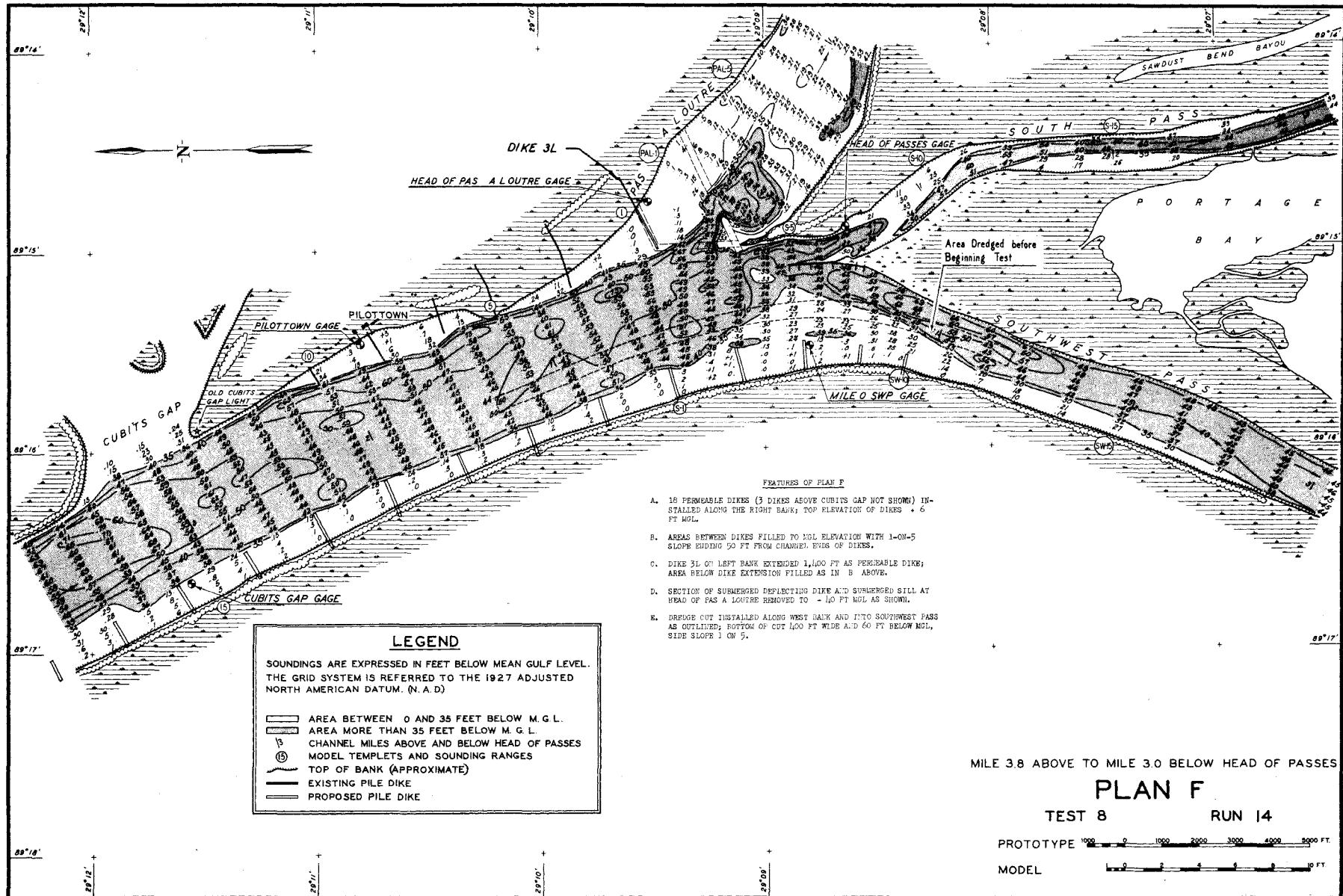


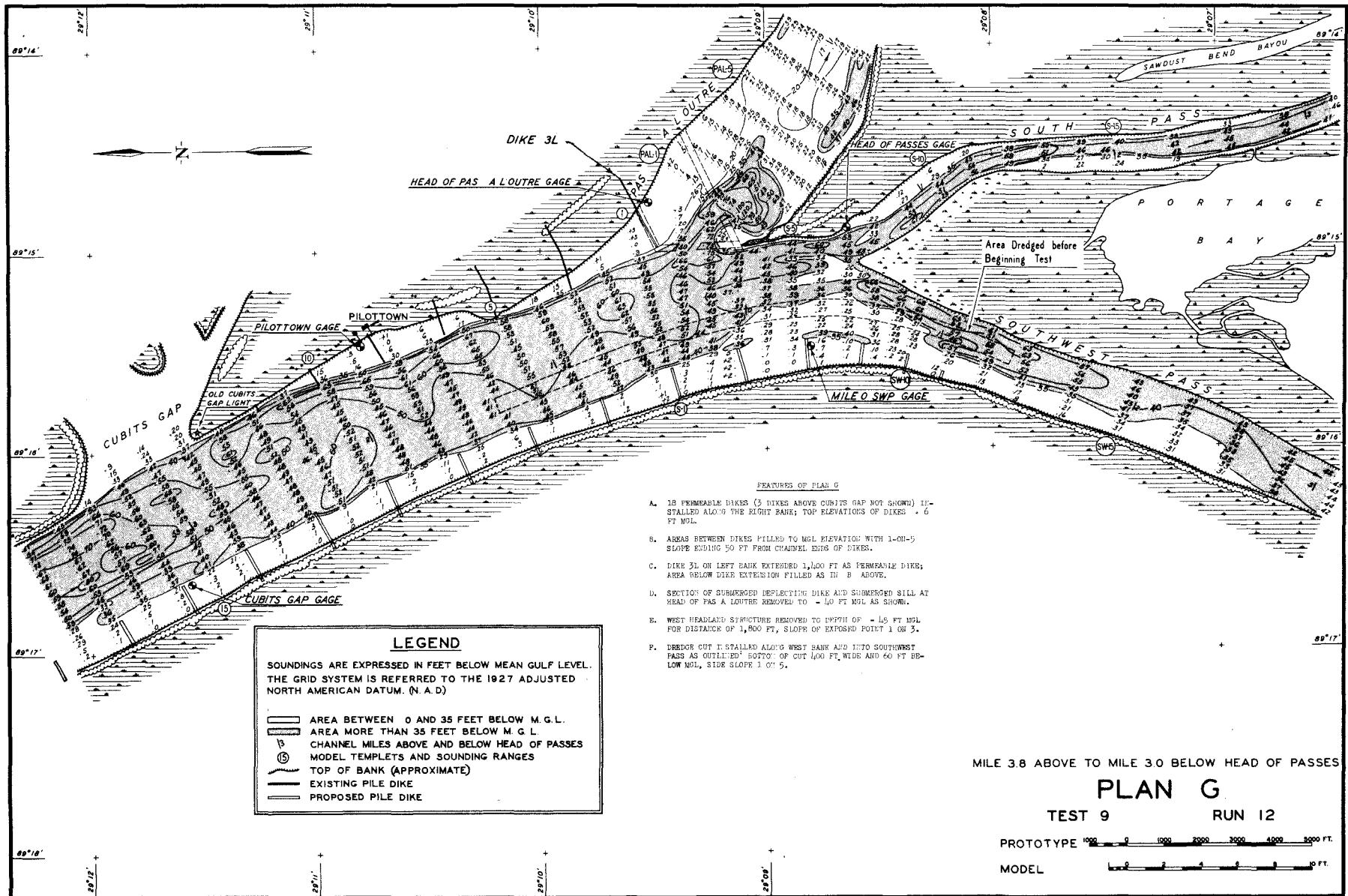


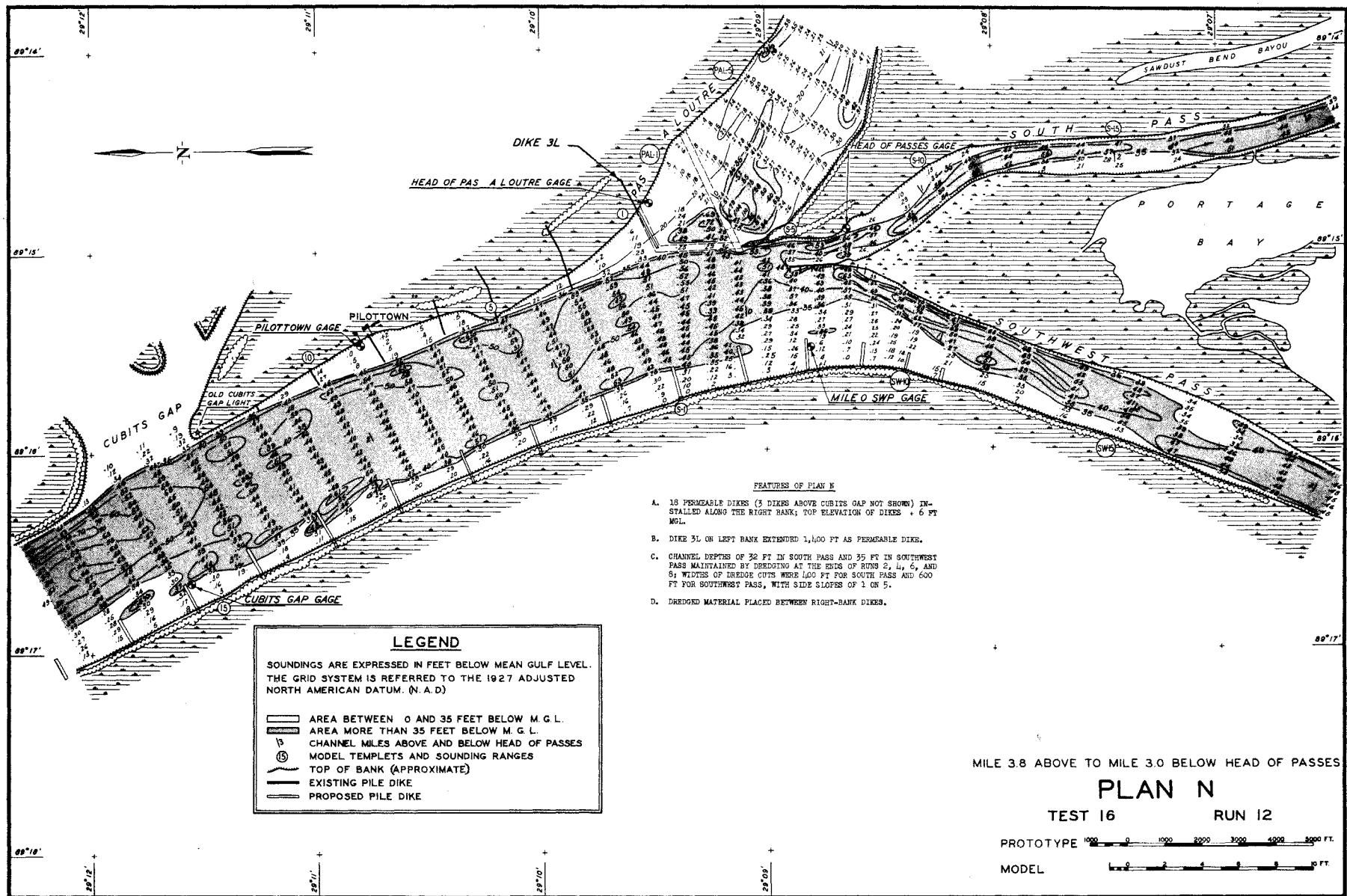


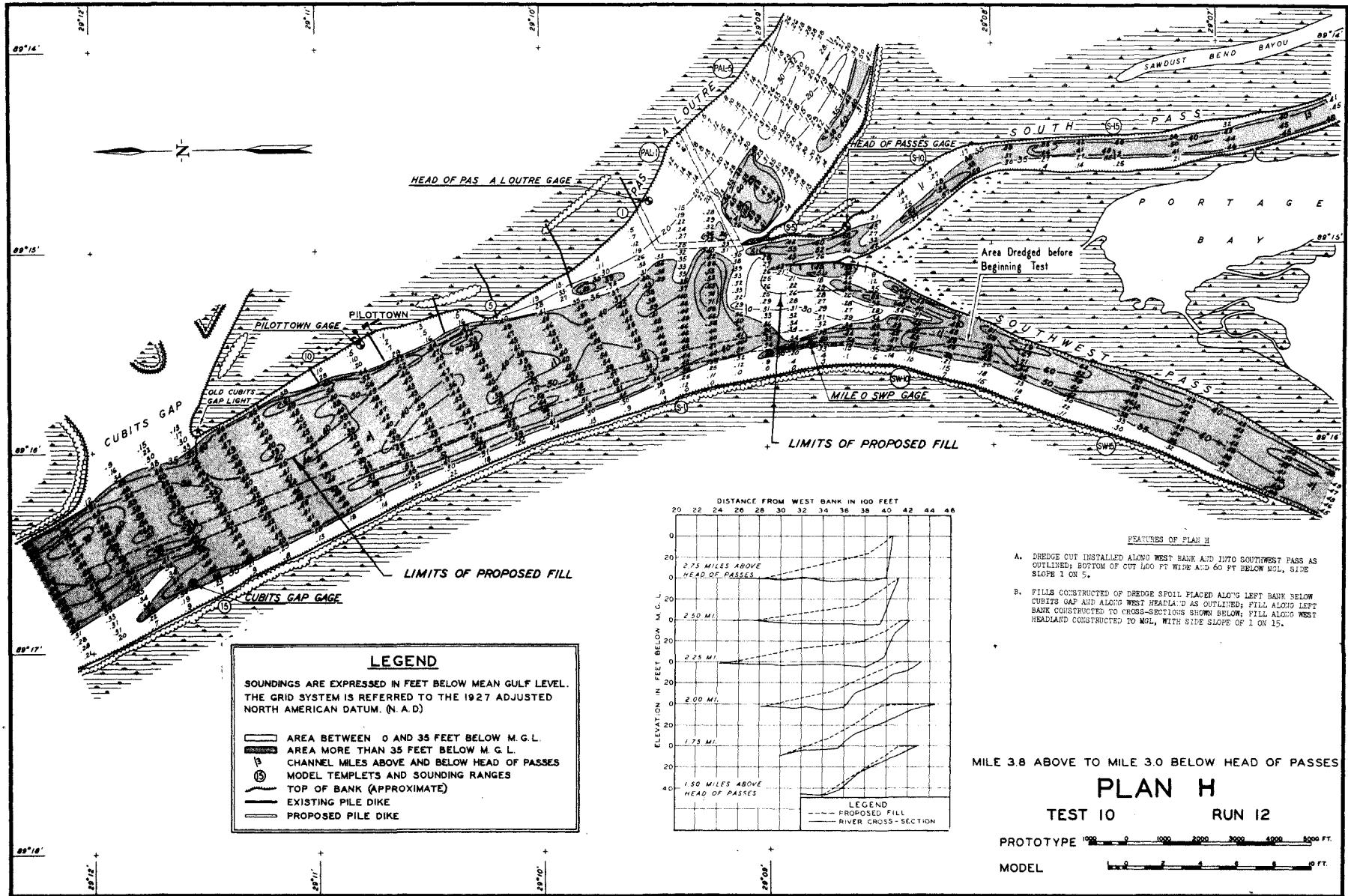


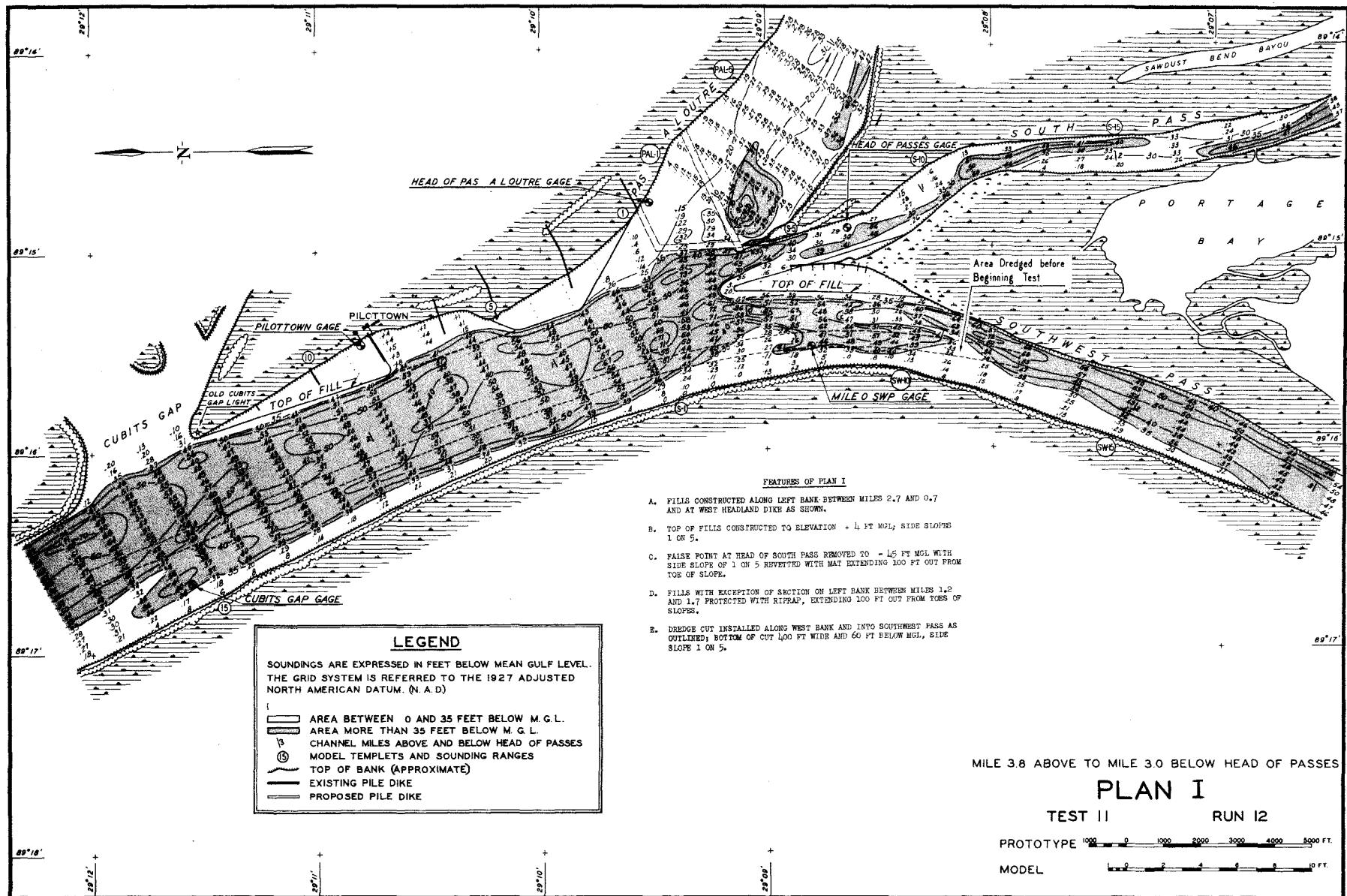


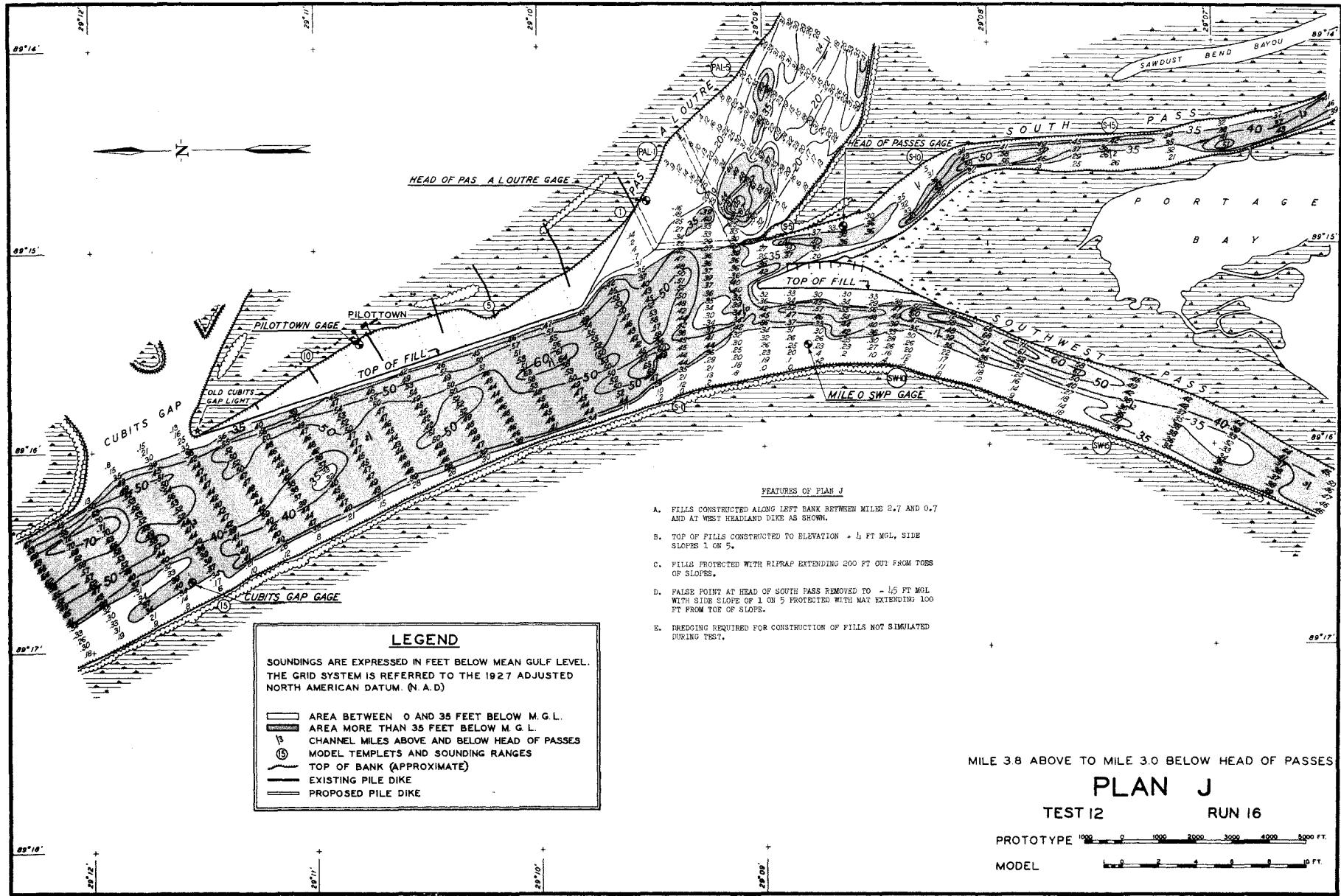


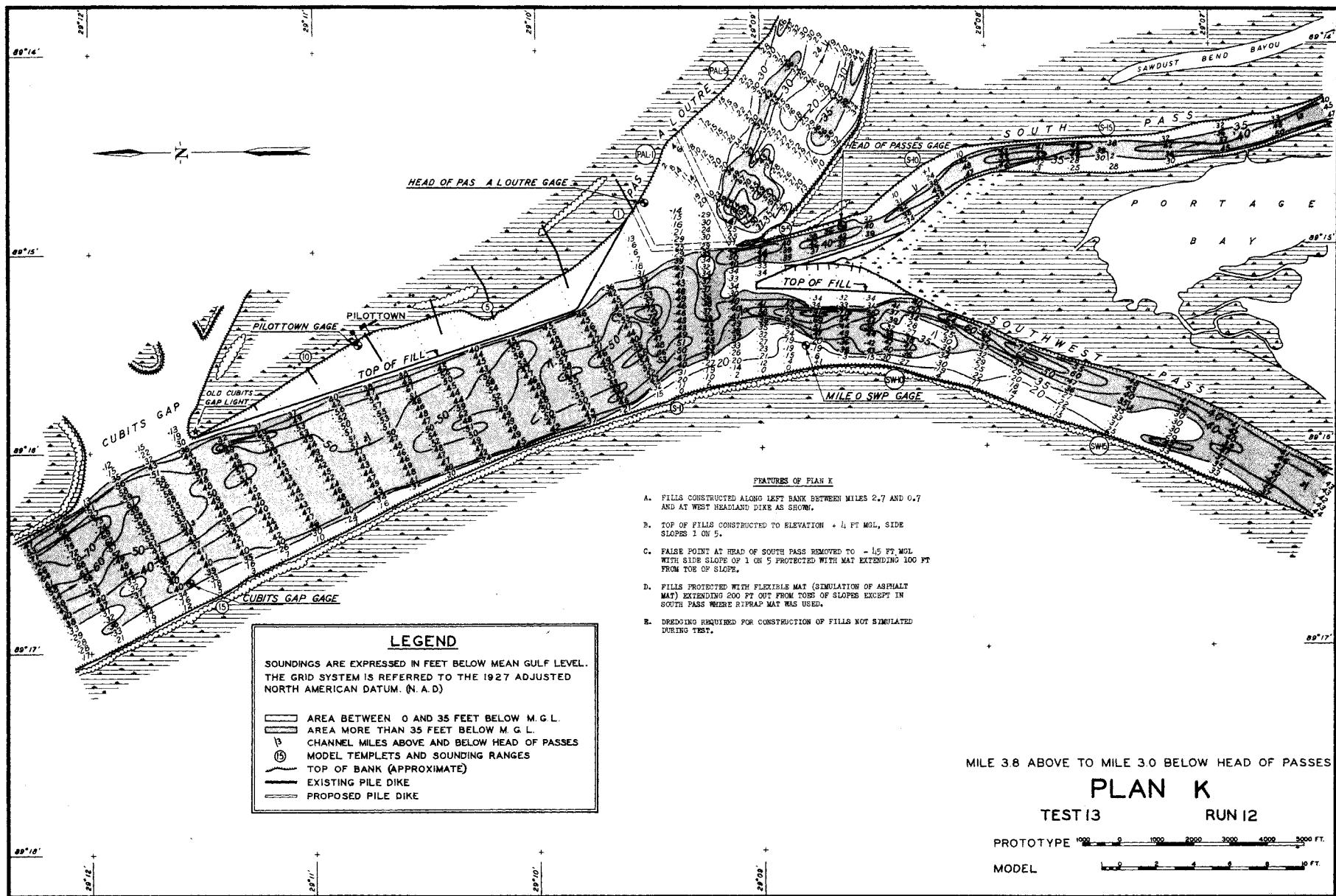


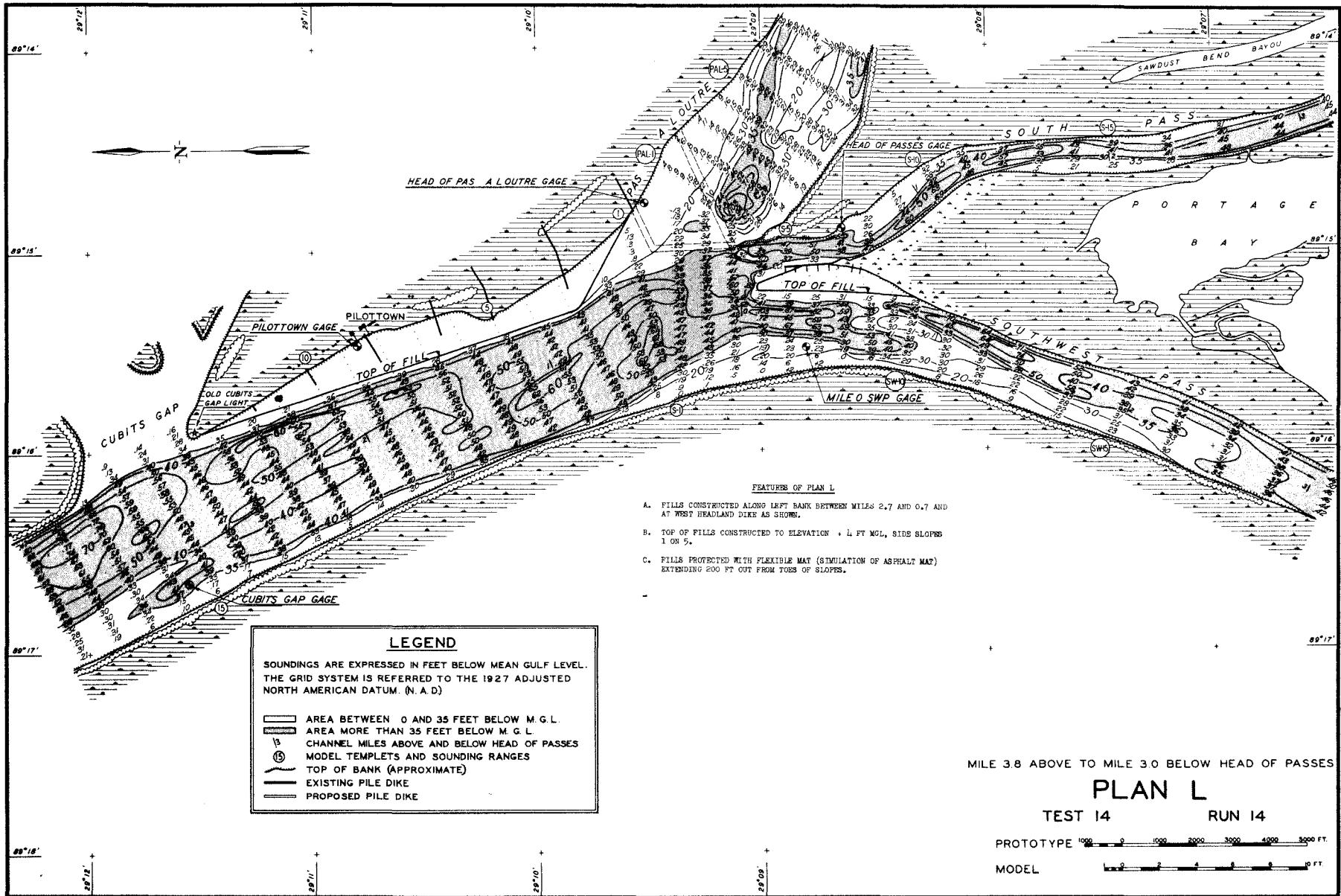


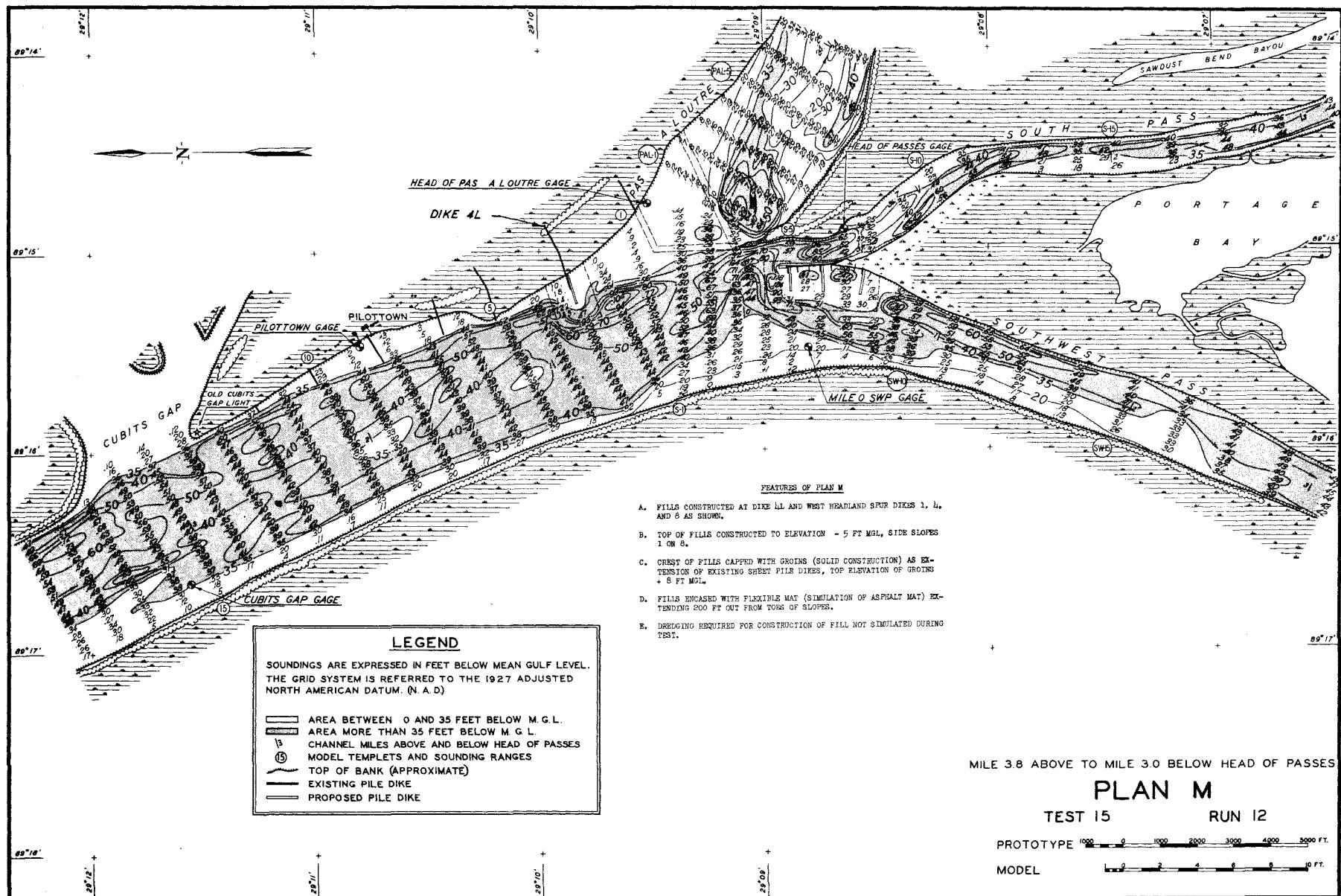


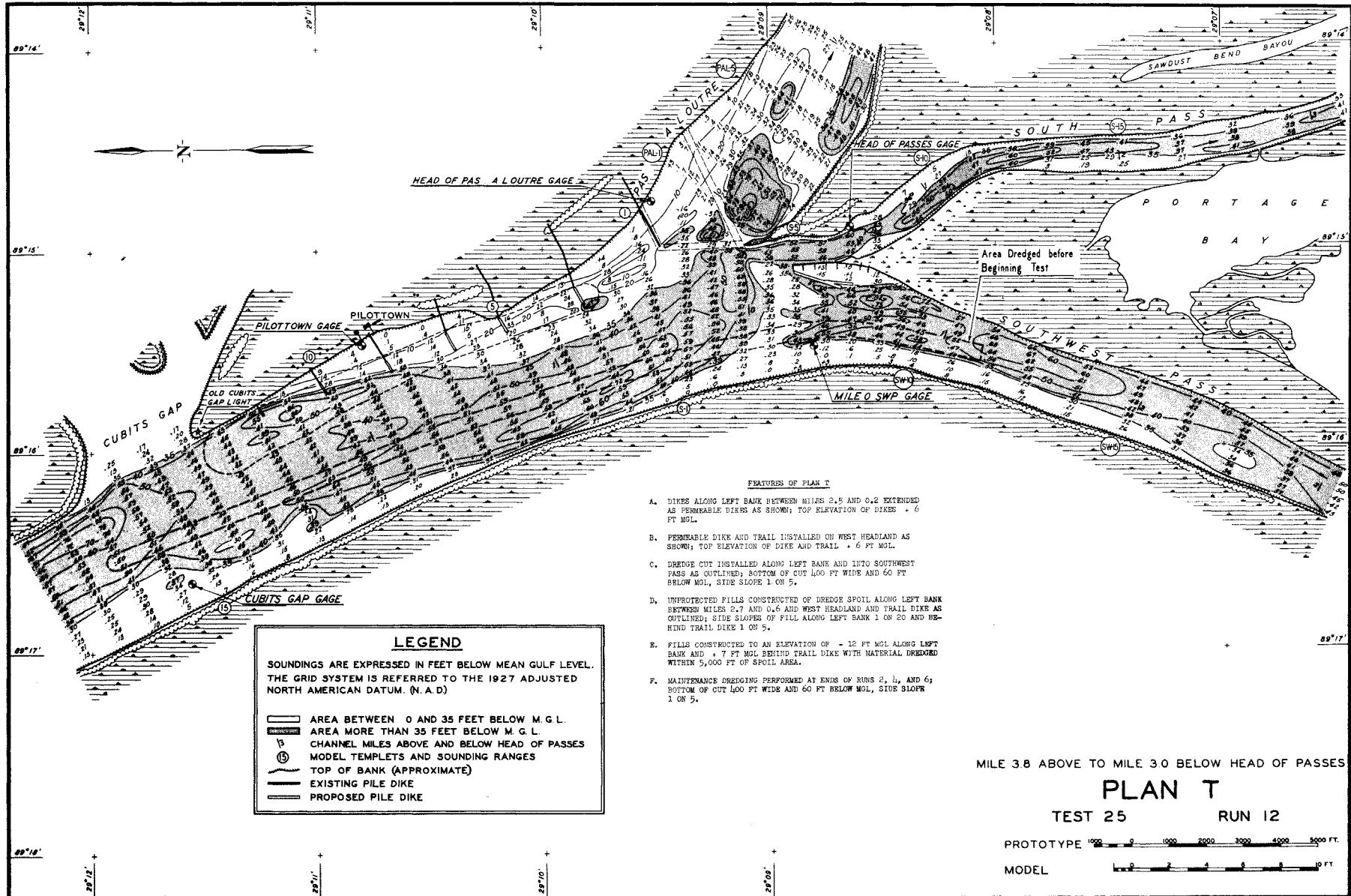


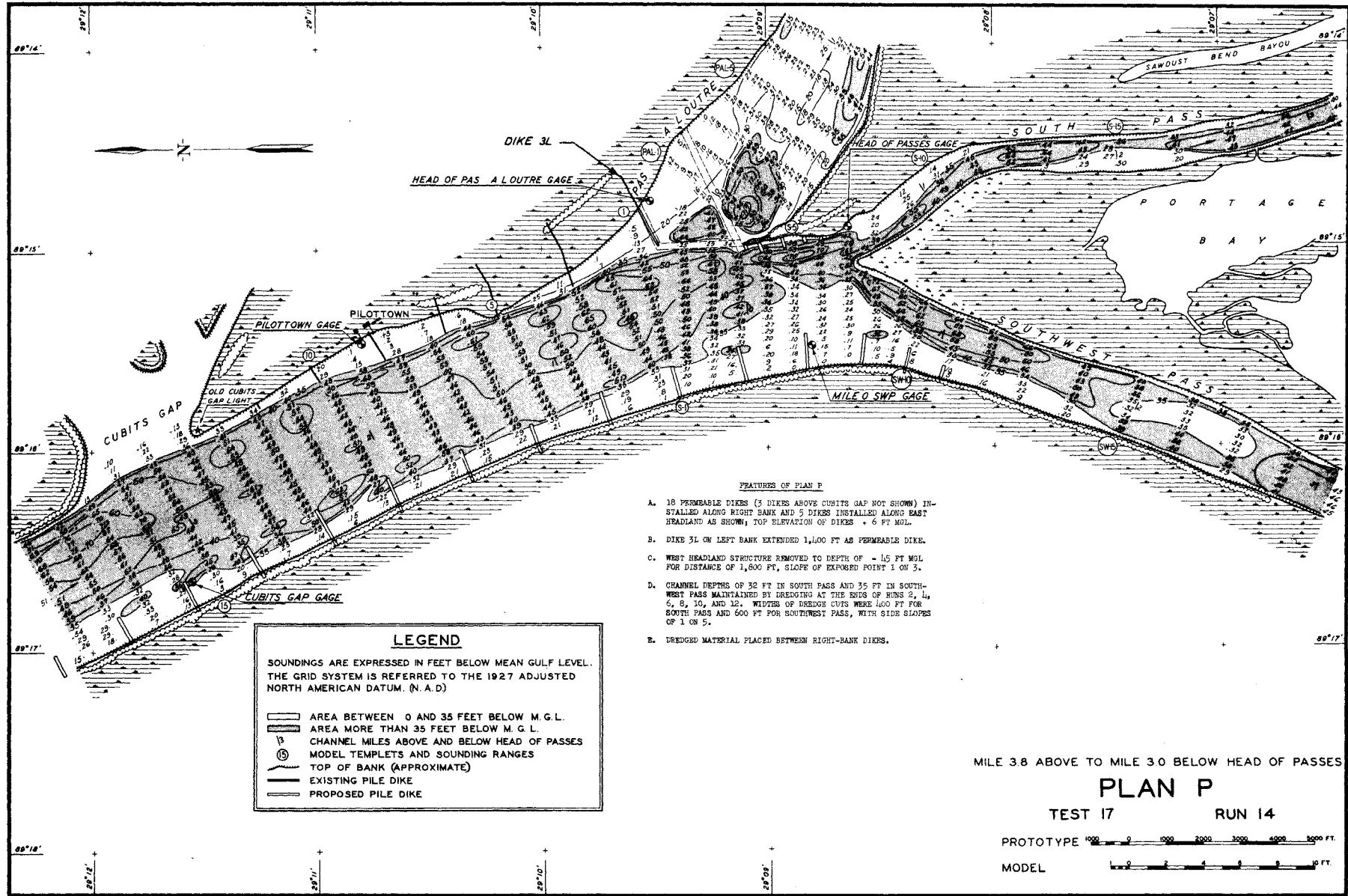


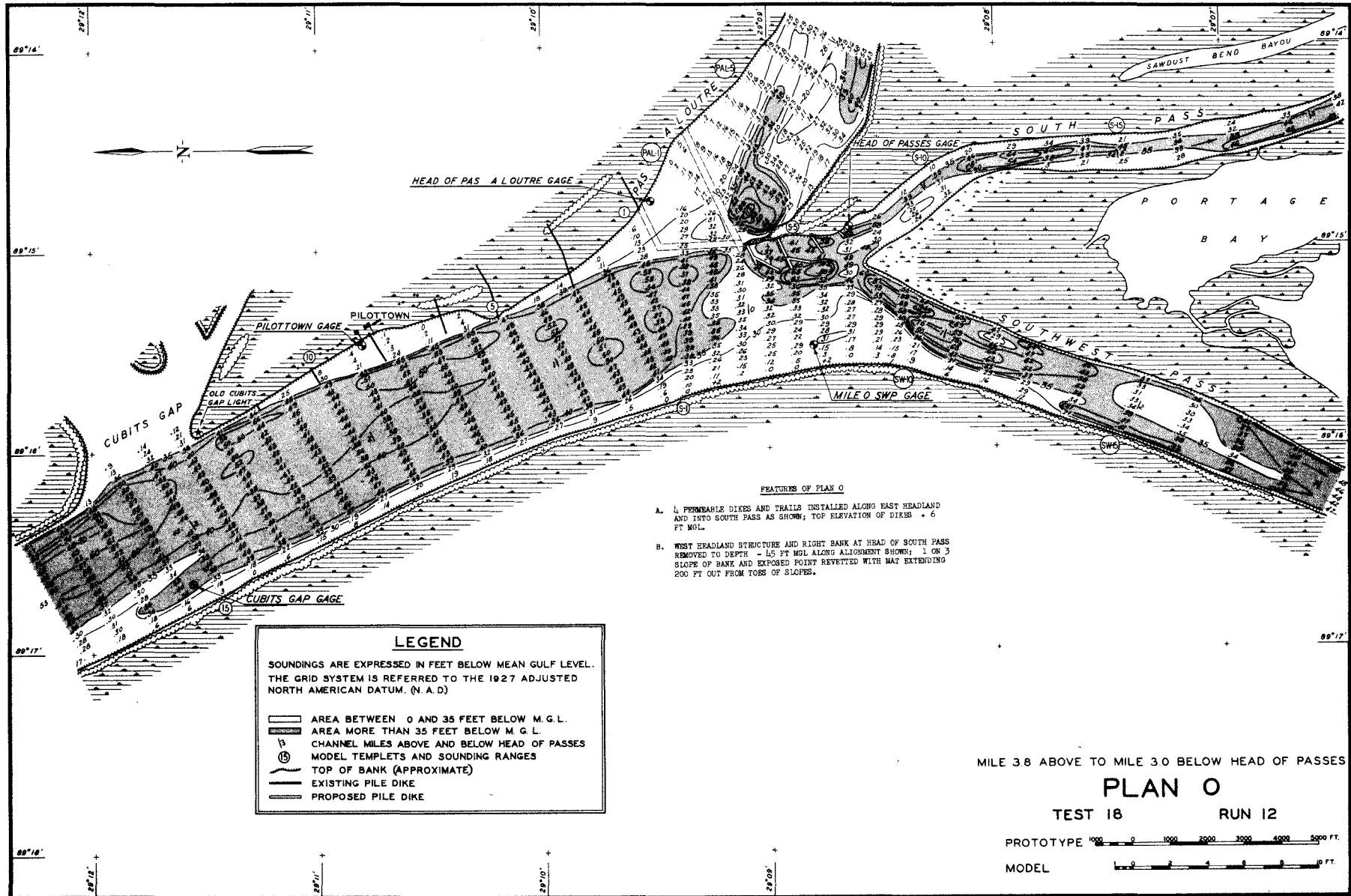


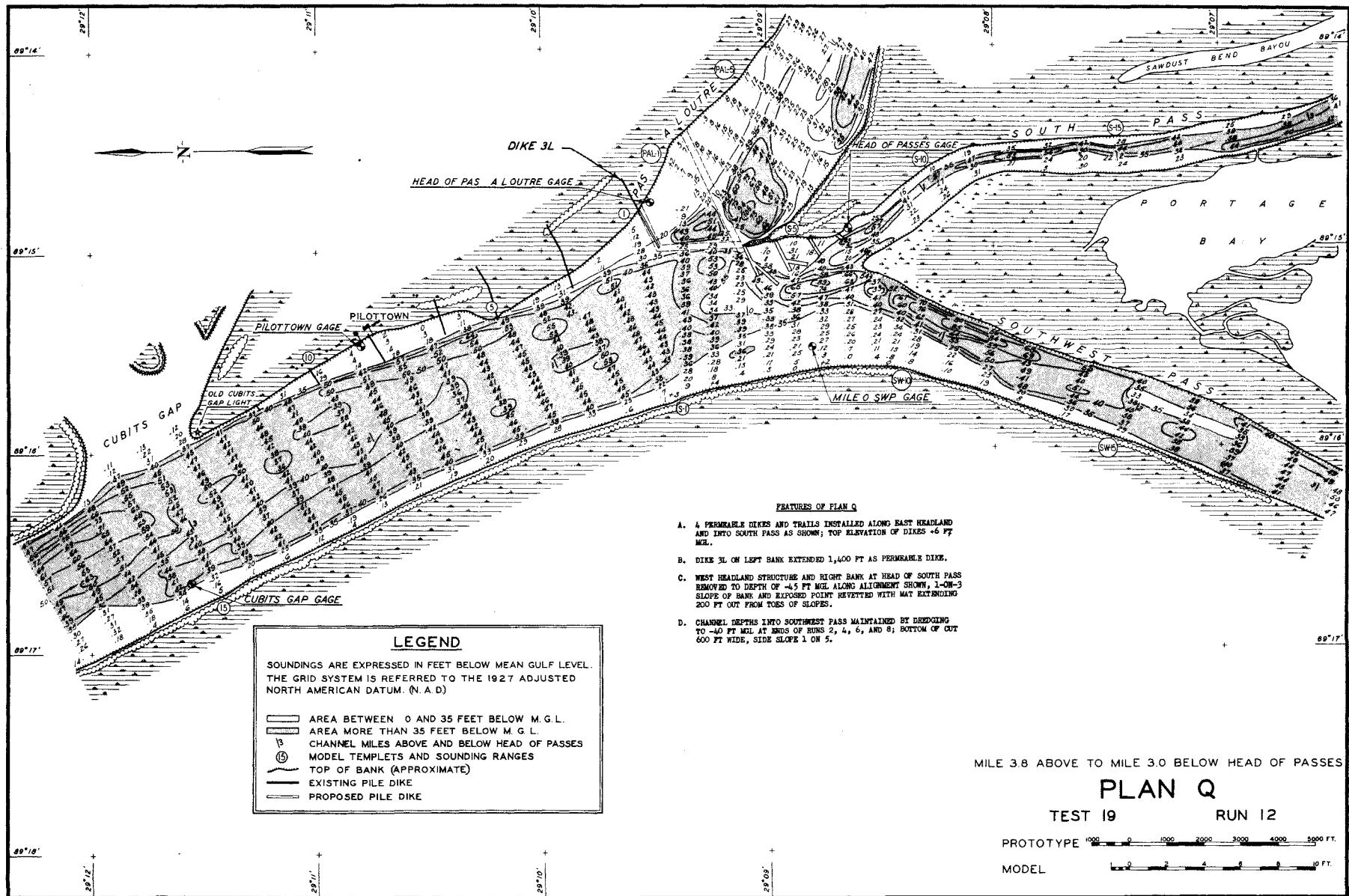


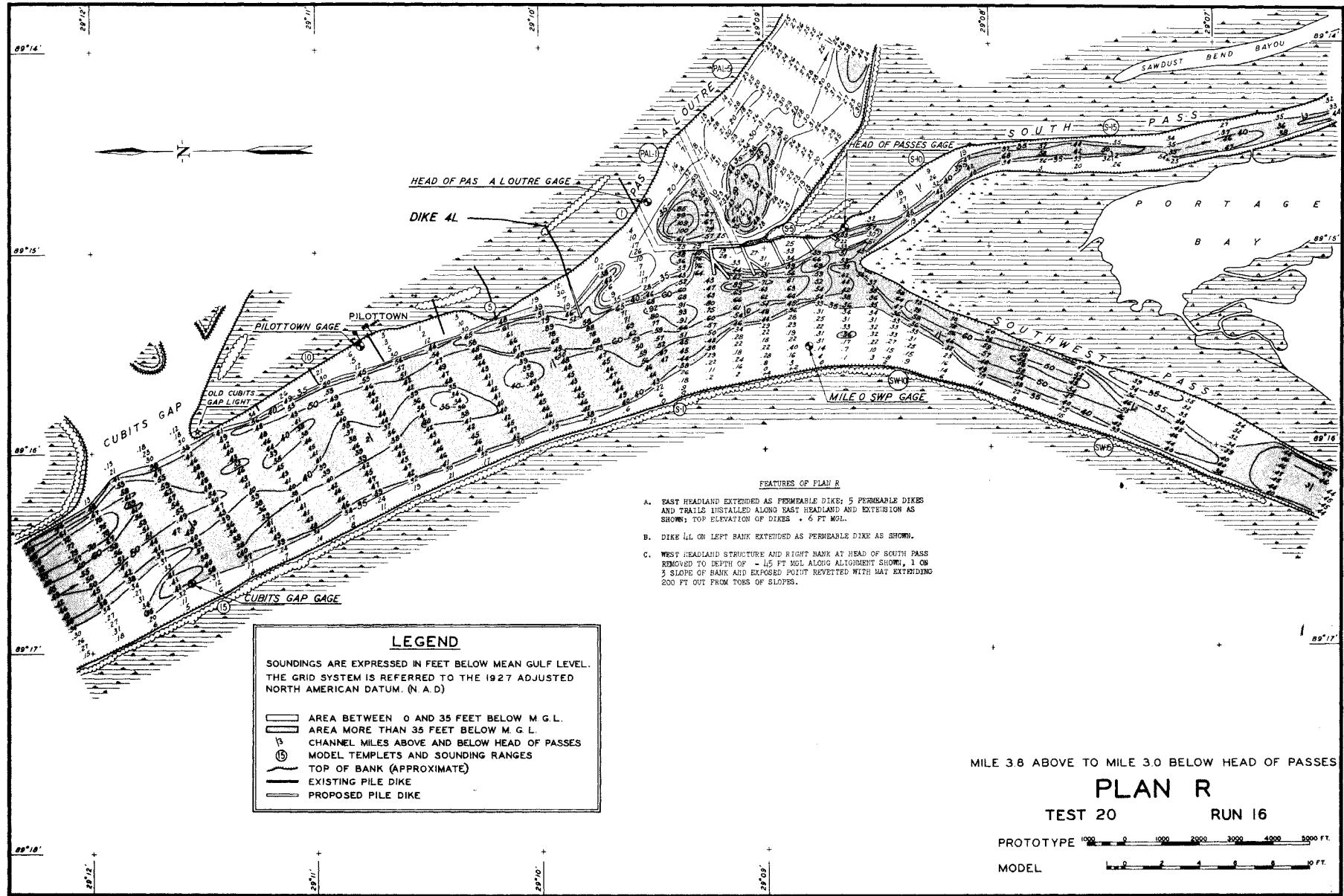


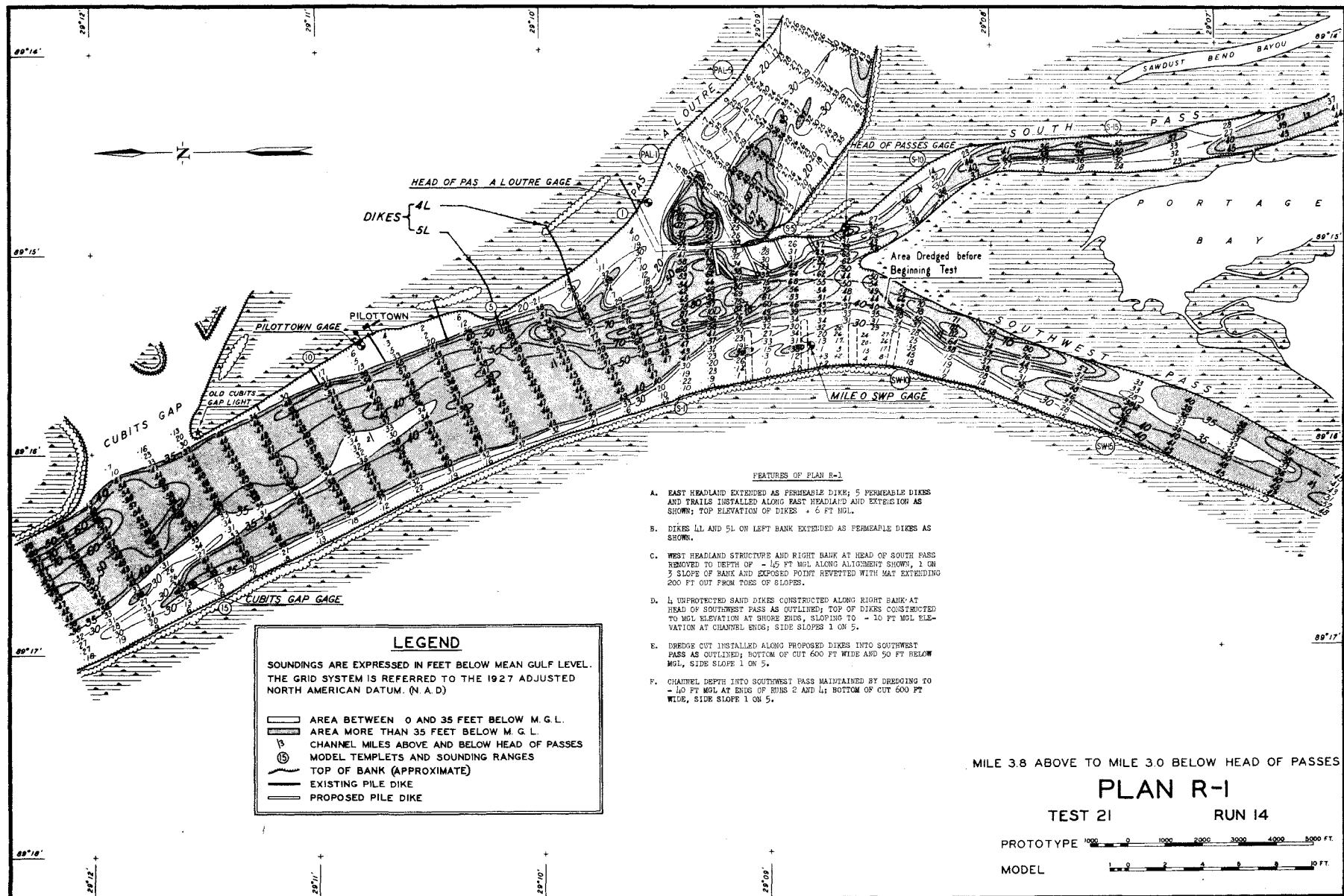


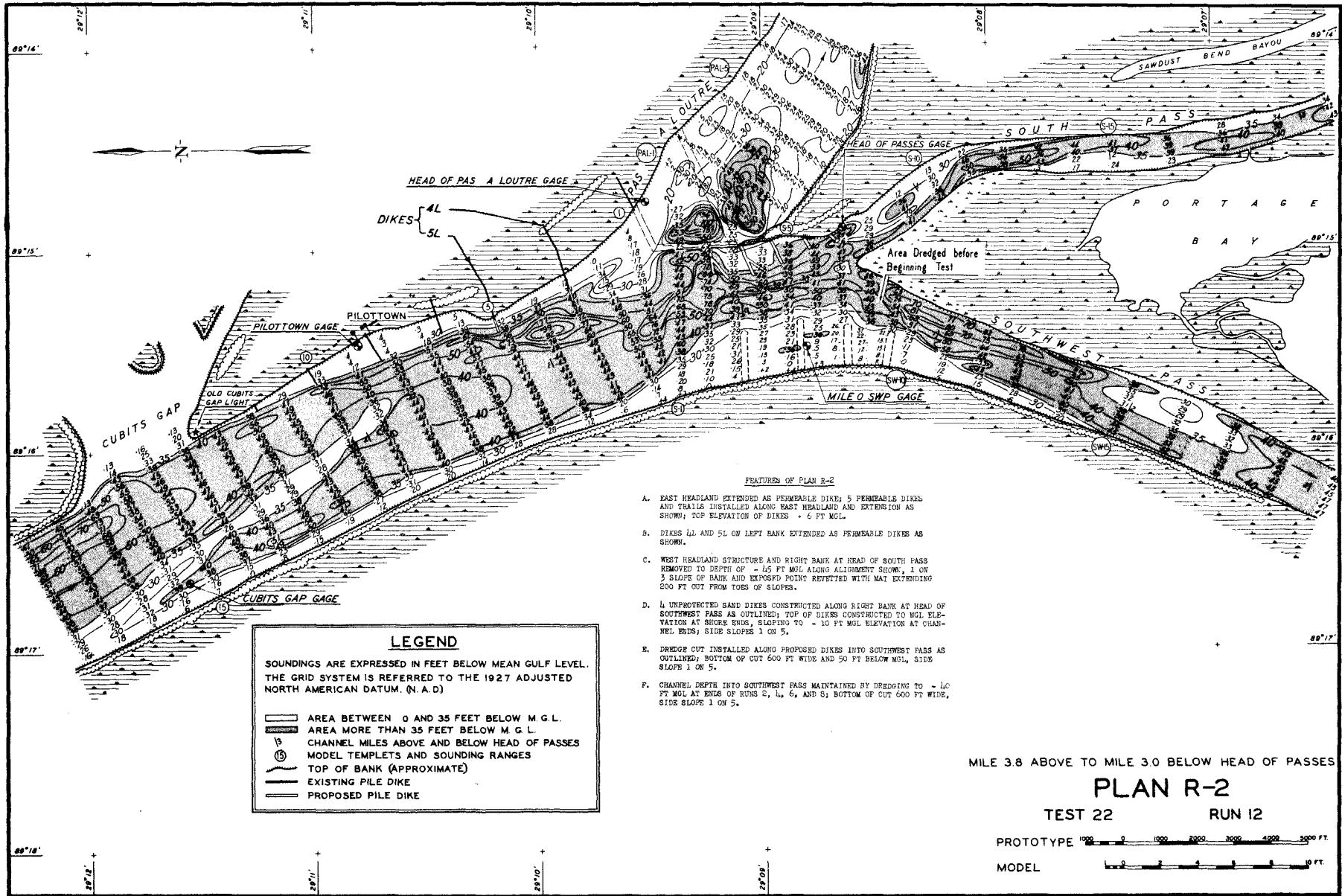


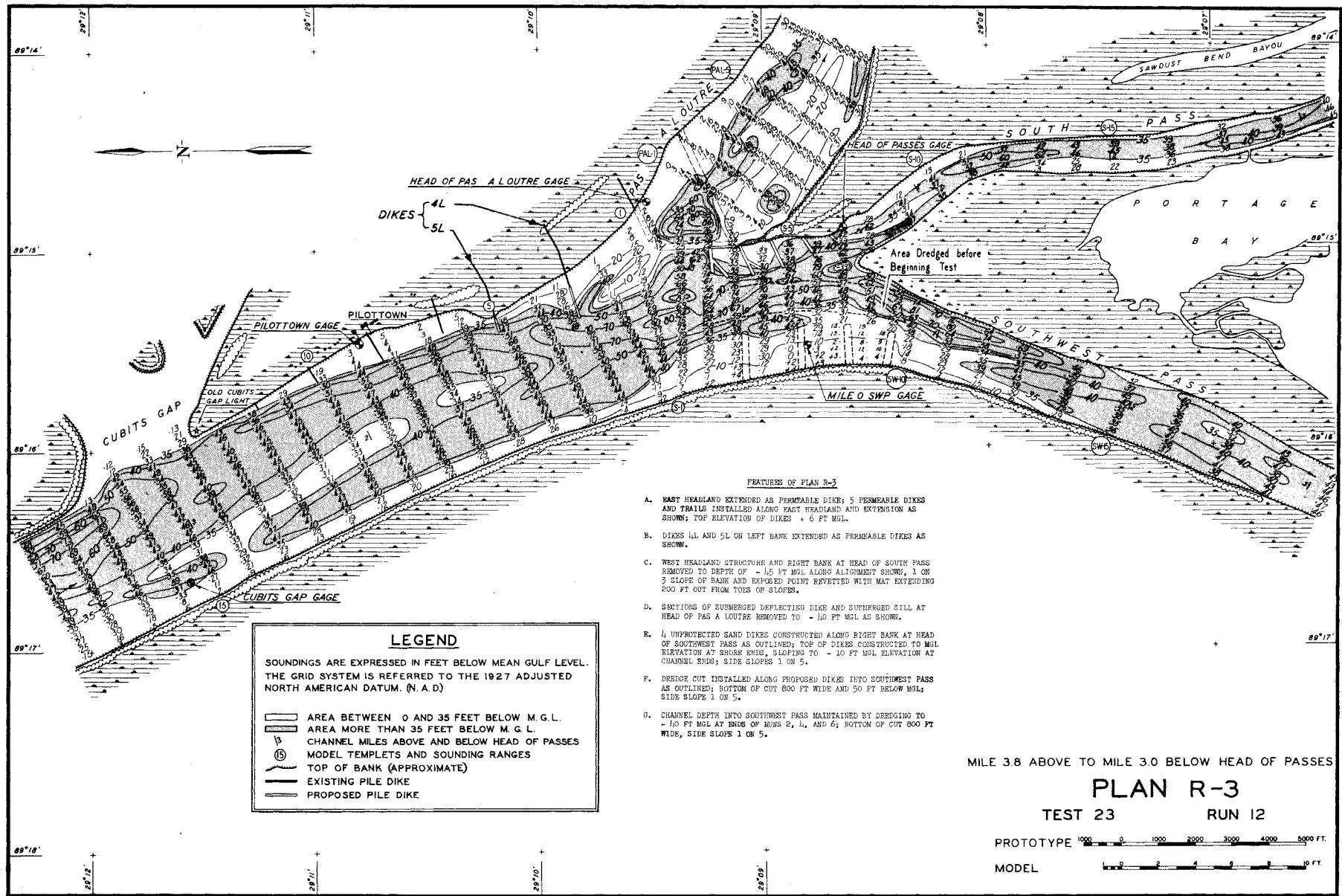


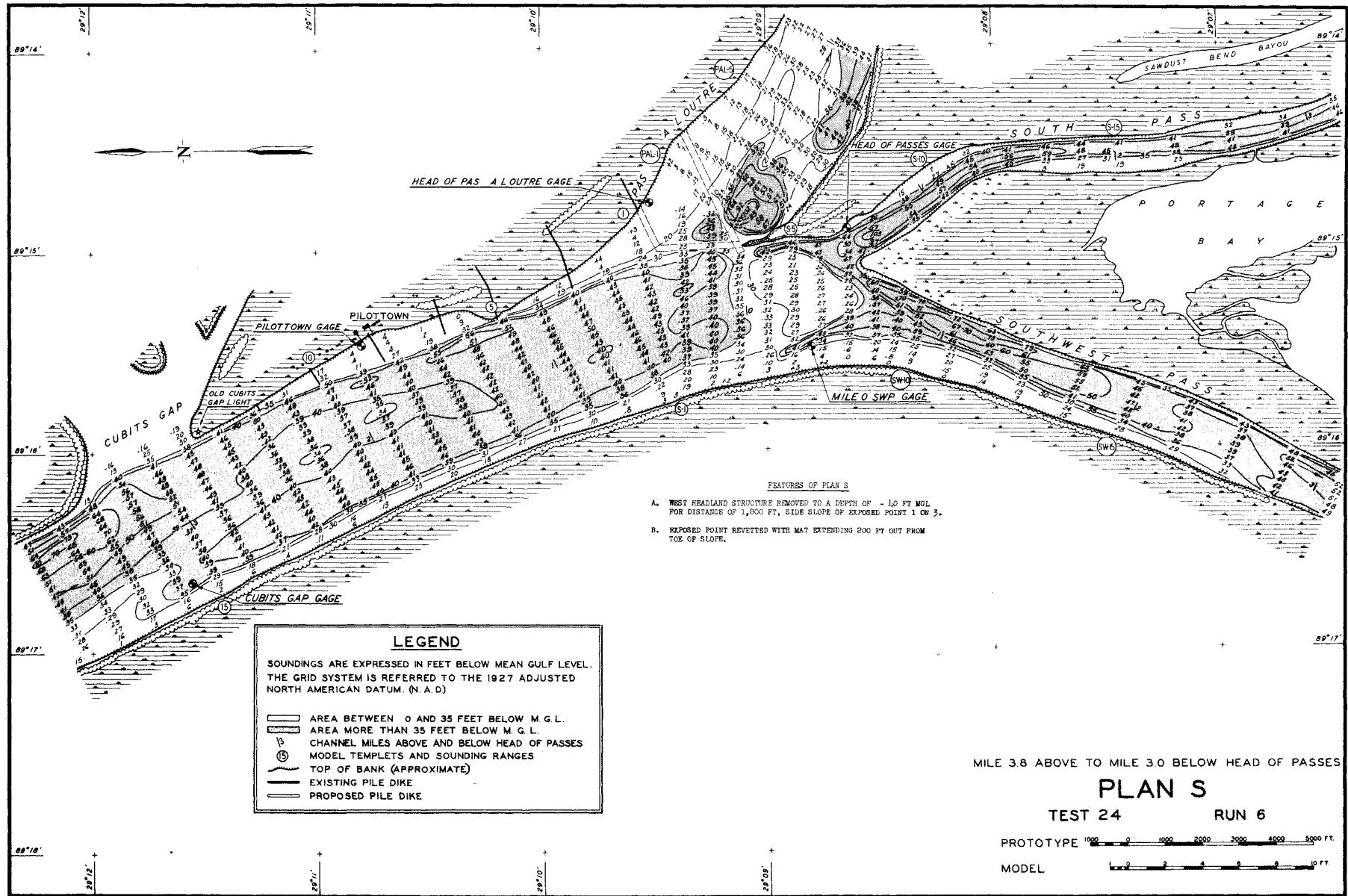


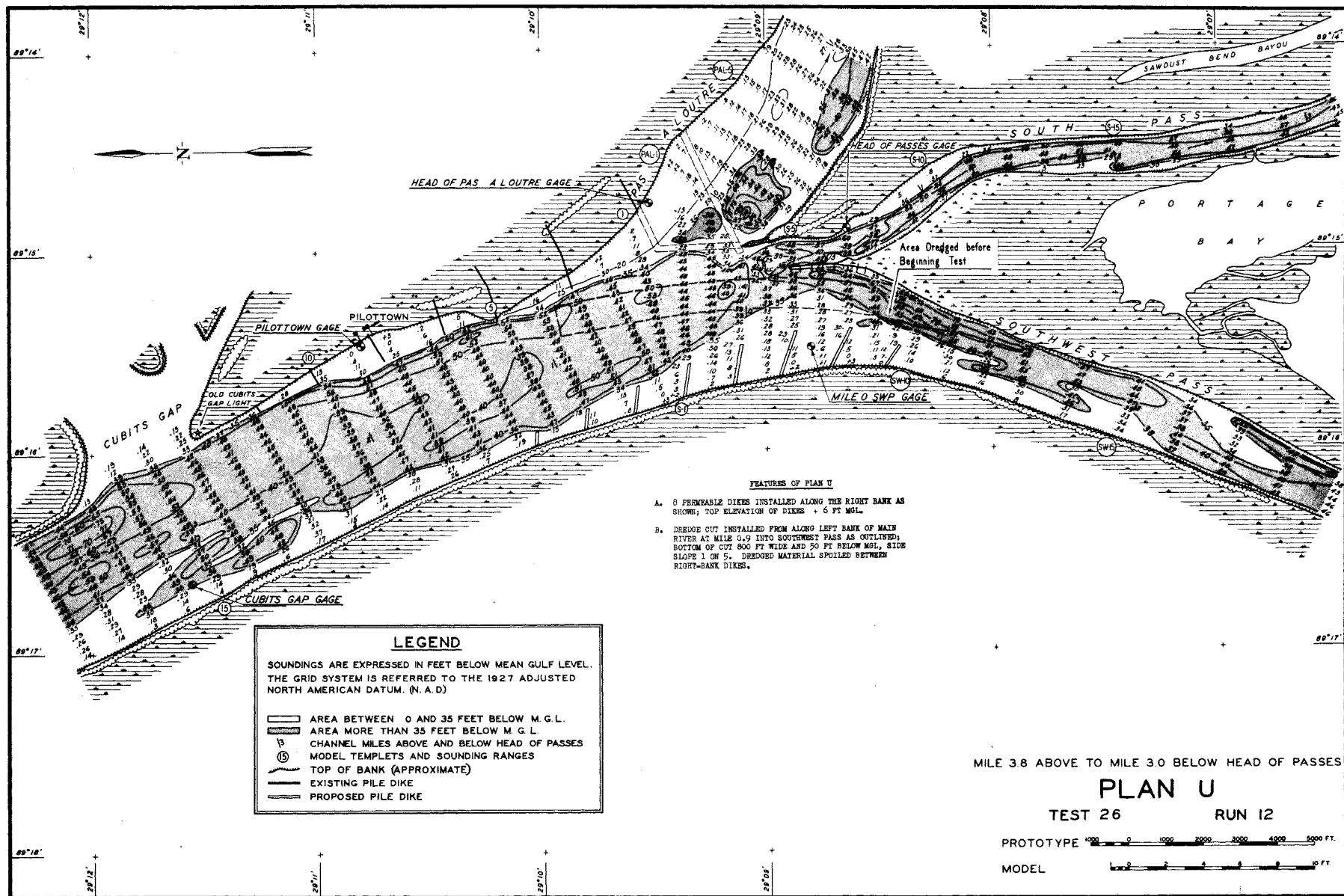


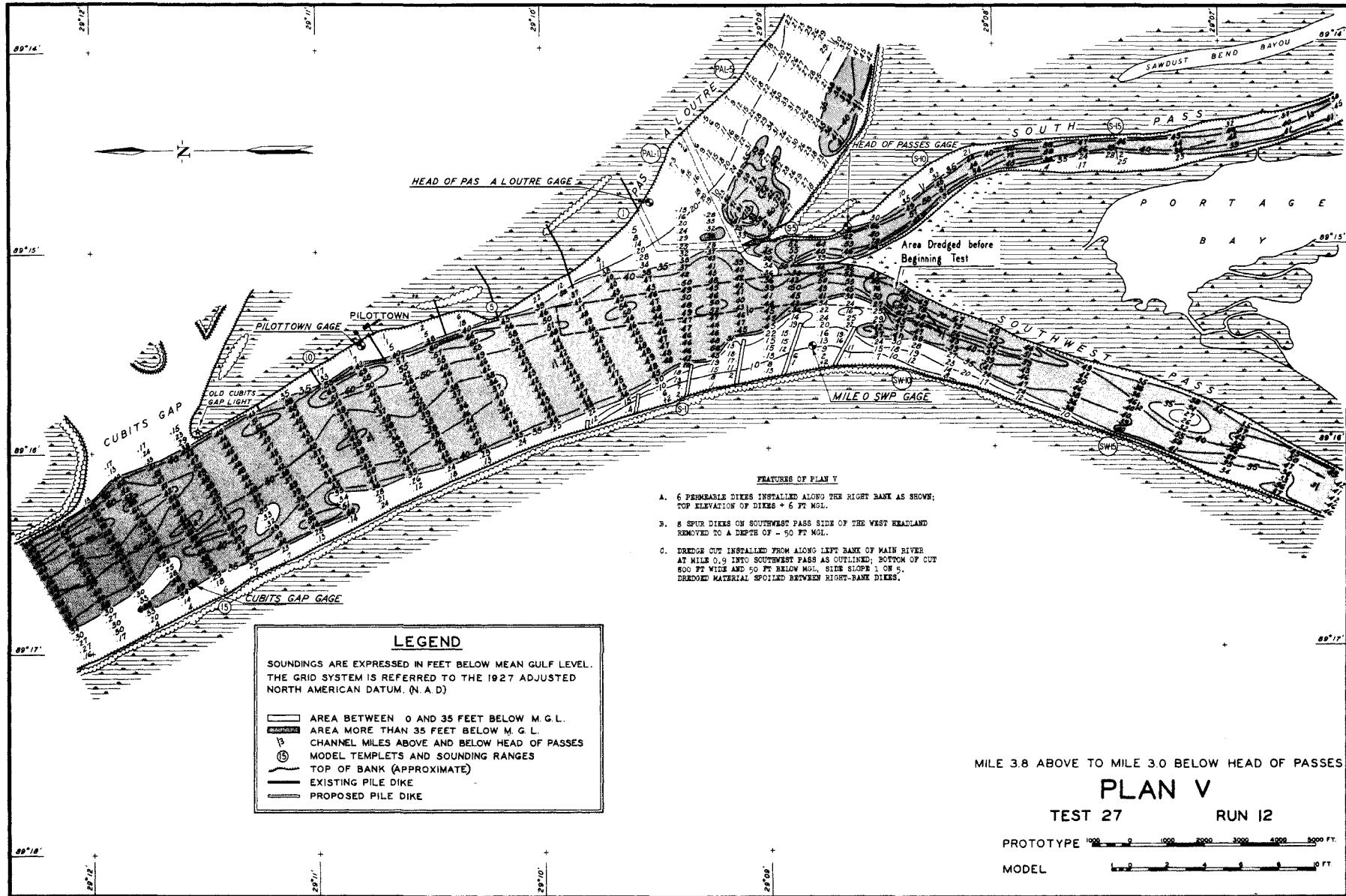


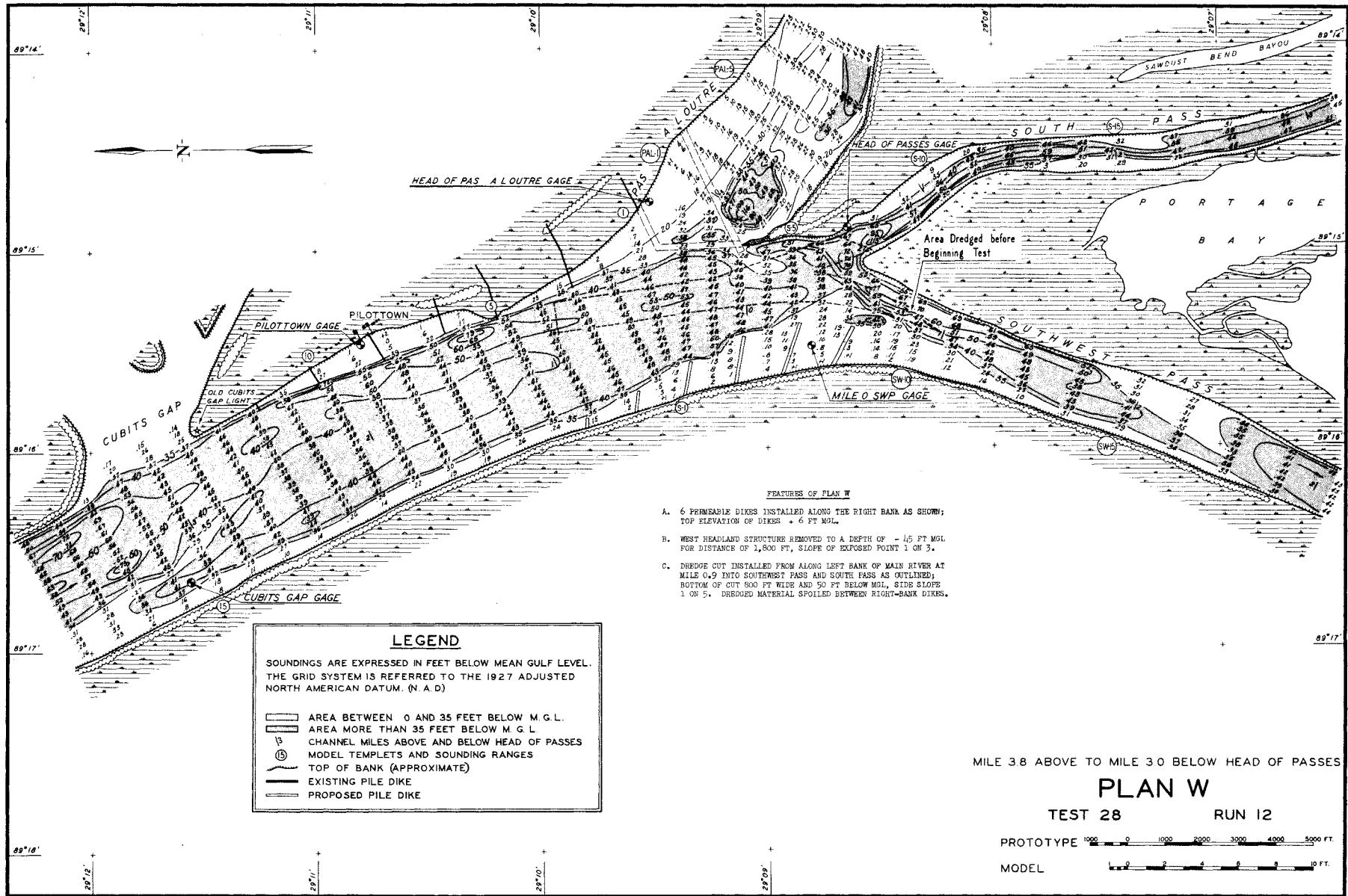


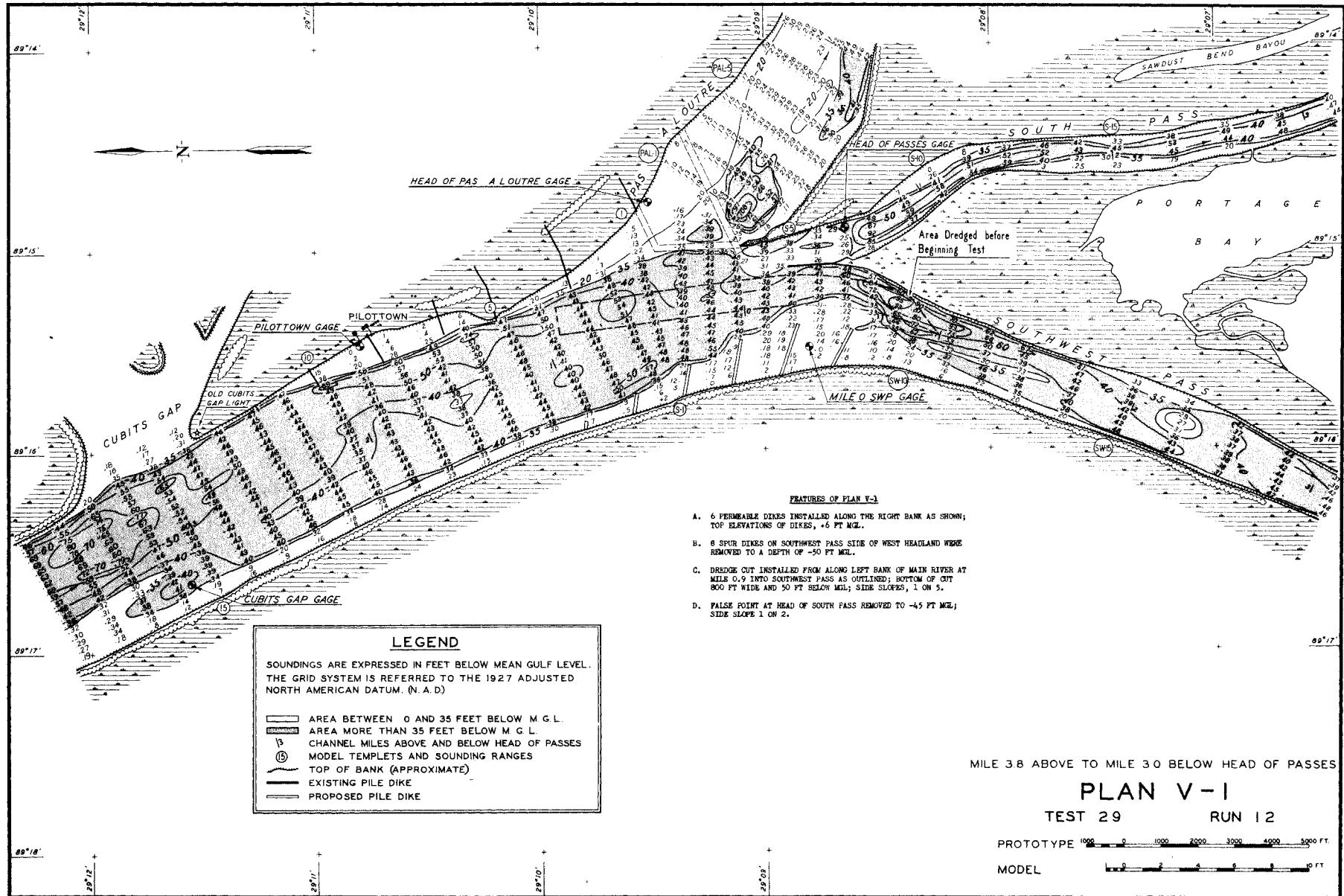












## APPENDIX

## APPENDIX

### ADDITIONAL TESTING PROGRAM

#### Purpose and Description of Additional Tests

1. After completion of the testing program described in the main report the two most favorable improvement plans developed (plans R-1 and V) were subjected to additional testing for the following purposes: (a) to check on the consistency of the model in repeating results; (b) to determine relative quantities of maintenance dredging that would be required while the river bed was adjusting itself to the proposed structures; and (c) to investigate the probable effects of a major flood upon the effectiveness of the proposed plans.

#### Test Procedure

2. The operating procedure for the additional tests was identical with that followed in previous tests of proposed improvement plans (see paragraphs 30-32 of main report), with the exception of the major-flood tests mentioned in (c) above. The operating procedure for the tests using a hydrograph including extreme flood flows was identical with that followed in the former average-hydrograph tests with one exception: the operation of the fourth run of each of these tests consisted of the simulation of a "major-flood hydrograph" furnished by the New Orleans District. Plate A1 presents both the average and major-flood hydrographs used. Table A1 shows discharge distributions among the three main passes for all of the additional tests. Table A2 shows quantities dredged during these tests.

Additional Base TestsDredging base test (test 32)

3. Description. This base test (test of existing prototype conditions) was similar to the original base test (test 2) except that a channel of 50-ft depth and 600-ft bottom width was dredged from 1 mile above Head of Passes to 1 mile below into Southwest Pass, and was maintained to a depth of 40 ft by periodic dredging throughout the test. The material removed in the initial and periodic maintenance dredging was spoiled along the right bank opposite the West Headland Dike. The purpose of this test was to provide dredging quantities, under existing prototype conditions, which would serve as a basis of comparison for evaluating similar data obtained in the subsequent dredging test of plan V.

4. Results (see plate A2). Results of the dredging base test were as follow:

- a. Channel above Head of Passes. The channel above Head of Passes remained fairly stable during the test. No appreciable change was reflected in this area by the changing of the dredge cut alignment or the spoil area. The results of this test indicate that a change in location of the dredge cut in the Head of Passes area would have no appreciable effect on the channel above Head of Passes.
- b. Southwest Pass. The entrance to Southwest Pass shoaled continually throughout the test, making periodic maintenance dredging necessary. Shoaling also occurred along the left bank at mile 2.5, filling the 40-ft channel in that area to a controlling depth of 39 ft.
- c. South Pass. Except for a small bar of 30-ft controlling depth forming across the entrance to South Pass, there was no appreciable change from the original base-test conditions in South Pass.

Major-flood base test (test 34)

5. Description. The major-flood base test was identical with the

original base test (test 2) except that the fourth run consisted of reproduction of the major-flood hydrograph described in paragraph 2 above. The purpose of the test was to provide a basis of comparison for evaluating the results of subsequent major-flood tests of plans R-1 and V.

6. Results (see plates A4 and A5 and photographs A1 and A2).

Plate A4 shows the results of this test at the end of the major flood of the fourth run, while plate A3 shows results of the fourth run of the original base test (test 2) for purposes of comparison. The final results of test 34 (see plate A5) were generally similar to the final results of the original base test, except that depths generally were somewhat greater and shoaling of the dredge cut in Southwest Pass was more rapid and complete owing to the unusually rapid movement of bed material during the major flood.

Additional Tests of Plan V

Check test of plan V (test 30)

7. Description (see plate A6). Plan V, test 27 (described in paragraph 91 of main report), produced a satisfactory self-maintained channel along a smooth sailing line into Southwest Pass. The repeat test of this plan, performed to check on the consistency of the model in determining the effects of improvement plans, was designated "plan V, test 30."

8. Results (see plate A6). The results of this test were generally similar to those obtained in test 27, plan V (see paragraph 92 of the main report). The variations which did occur were not serious and had no detrimental effect on channel development or alignment. Therefore,

the results of tests 27 and 30 appear to indicate that, under conditions similar to those which have occurred in the past, plan V would effect a self-maintained navigable channel in the head of Southwest Pass after sufficient high water had occurred to adjust the river bed to the proposed structures.

Dredging test of plan V (test 31)

9. Description (see plate A7). Plan V, test 31, was similar to plan V, test 27 (see paragraph 91 of main report), except that the dredge cut was made 600 ft wide instead of 800 ft, and was maintained to a depth of 40 ft during the initial development of the plan in order to determine the relative amount of maintenance dredging that would be required.

10. Results (see plate A7). The final results of the test of plan V, including periodic maintenance dredging, were generally similar to the final results of previous tests of this plan. Channel depths of 40 ft were maintained in the initial dredge cut by periodic maintenance dredging throughout the test. However, after the sixth year of operation, the plan produced a self-maintained channel suitable for navigation over a bottom width of 700 ft, and this self-maintained channel improved steadily as operation continued.

Major-flood test of plan V (test 35)

11. Description (see plates A9 and A10). This test was identical with the original test of plan V, test 27 (see paragraph 91 of main report), except that the fourth run was based on the major-flood hydrograph.

12. Results (see plates A9 and A10 and photographs A3 and A4). Plate A9 shows the condition of the model bed at the end of the major flood of the fourth run, at which time a bar of considerable size had formed in

the channel above Head of Passes and a narrow bar had developed in Southwest Pass between miles 1 and 2. Plate A8 shows results at the end of the fourth run of the original test (test 27) of plan V for purposes of comparison. By the end of the test (see plate A10) most of the upper bar had been scoured away, but the narrow shoal in Southwest Pass persisted. Sufficient high water had not occurred, after the major flood, to produce the wide channel of 40-ft depth obtained in previous tests of this plan.

#### Additional Tests of Plan R-1

##### Check test of plan R-1 (test 33)

13. Description (see plate A11). Plan R-1, test 33, was an identical repetition of plan R-1, test 21 (described in paragraph 81 of main report), and was conducted as a check on the consistency of the model.

14. Results (see plate A11). The results of this test were generally similar to those of plan R-1, test 21. The accuracy with which the model reproduced the bed configuration of test 21 can be determined by comparing plate 26 of the main report with plate A11. Channel depths of 40 ft were obtained over a bottom width of 600 ft, after the end of run 4 of test 21 and run 6 of test 33. In general, however, the results of the repeat test were an excellent reproduction of the original test of this plan, since all important tendencies and bed configurations were obtained.

##### Major-flood test of plan R-1 (test 36)

15. Description (see plate A13). The use of the major-flood hydrograph, instead of the average hydrograph, during the fourth run of this

test was the only variation between plan R-1, test 36, and plan R-1, test 21 (described in paragraph 81 of the main report).

16. Results (see plates A13 and A14 and photographs A5 and A6).

Plate A13 shows the results of this test at the end of the major flood (fourth run), while plate A12 shows results of the fourth run of the original test (test 21) of plan R-1 for purposes of comparison. The final results of plan R-1, test 36, were generally similar to the final results of plan R-1, test 21 (compare plate A14 with plate 26 of main report).

Summary of Results

17. The results of the additional tests conducted on the Head of Passes model are presented in tables A1 to A3, and on plates A2 to A14. The principal conclusions derived from the results of the additional tests are presented in the following paragraphs.

18. The model discharge distribution in the three main passes is shown in table A1. It will be noted that the percentile discharge carried by Southwest Pass during the tests of extreme conditions of flow (tests 34, 35, and 36) was slightly higher than in the tests of proposed improvement plans. This increase in percentile discharge in Southwest Pass is a reflection of the cross-sectional area relationship between South and Southwest Passes as stage heights increase.

19. The consistency of the model was established satisfactorily by the results obtained from the repetition of tests of plan R-1 and plan V. While variations may be observed between actual soundings, it will be noted that all important tendencies and bed configurations were reproduced.

Table A2 presents volumes of initial and periodic maintenance dredging performed during the additional tests (tests 31, 32, and 33 included periodic maintenance dredging).

20. In general, the results in the model appear to show no very great change as a result of simulation of the major-flood hydrograph during the fourth of the 12 runs of each of the tests. One outstanding result of the major flood noted during the base test was the much more rapid shoaling of the existing dredged channel adjacent to the right bank in the head of Southwest Pass, with some accompanying increase in central channel depths. The major flood also appeared to increase scouring action along the ends of dikes in the model.

21. There is, of course, no definite basis for the interpretation of the results of these major-flood tests in terms of prototype results, since the model verification did not include stages of such magnitude. However, relying on judgment alone, it is considered probable that the results of the major-flood tests provide an approximate indication of prototype results.

## **TABLES**

Table Al  
DISCHARGE DISTRIBUTION

Plan	Test No.	Per Cent of Total Discharge at Head of Passes		
		Pas a Loutre	South Pass	Southwest Pass
Base test (dredging)	32	44.0	17.1	38.9
Base test (major flood)	34	44.0	16.7	39.3
Plan V (check test)	30	44.0	17.4	38.6
Plan V (dredging)	31	44.0	17.3	38.7
Plan V (major flood)	35	44.0	16.8	39.2
Plan R-1 (check test)	33	42.9	17.2	39.9
Plan R-1 (major flood)	36	42.7	17.1	40.2

Table A2  
INITIAL AND PERIODIC MAINTENANCE DREDGING  
PERFORMED DURING TESTS

Plan	Test No.	Initial Dredge Cut			Maintenance Dredging			Total Dredging in 1,000 Cu Yd
		Dimensions	Amount in 1,000 Cu Yd	No. of Cuts	Dimensions	Amount in 1,000 Cu Yd	Average in 1,000 Cu Yd	
Base test (dredging)	32	600 x 50	2,778	5	600 x 40	2,942	588	5,720
Base test (major flood)	34	-	-	-	-	-	-	-
Plan V (check test)	30	800 x 50	3,473	-	-	-	-	3,473
Plan V (dredging)	31	600 x 50	2,458	5	600 x 40	1,153	231	3,611
Plan V (major flood)	35	800 x 50	3,125	-	-	-	-	3,125
Plan R-1 (check tests)	33	600 x 50	1,625	3	600 x 40	514	171	2,139
Plan R-1 (major flood)	36	600 x 50	1,597	2	600 x 40	111	55	1,708

Table A3

ENTRANCE CHANNEL - SOUTHWEST PASS

Plan	Test No.	Controlling Depth in Ft below mG1	Minimum Width in Ft	
			35-ft Channel	40-ft Channel
Base test (dredging)	32	38	900	-
Base test (major flood)	34	32	-	-
Plan V (check test)	30	45	1,000	800
Plan V (dredging)	31	45	800	700
Plan V (major flood)	35	41	800	400
Plan R-1 (check test)	33	53	1,000	900
Plan R-1 (major flood)	36	48	900	800

## **PHOTOGRAPHS**



Photograph A1. Base test; test 3<sup>4</sup>. Downstream view of Head of Passes area showing current alignment during the 17-ft stage



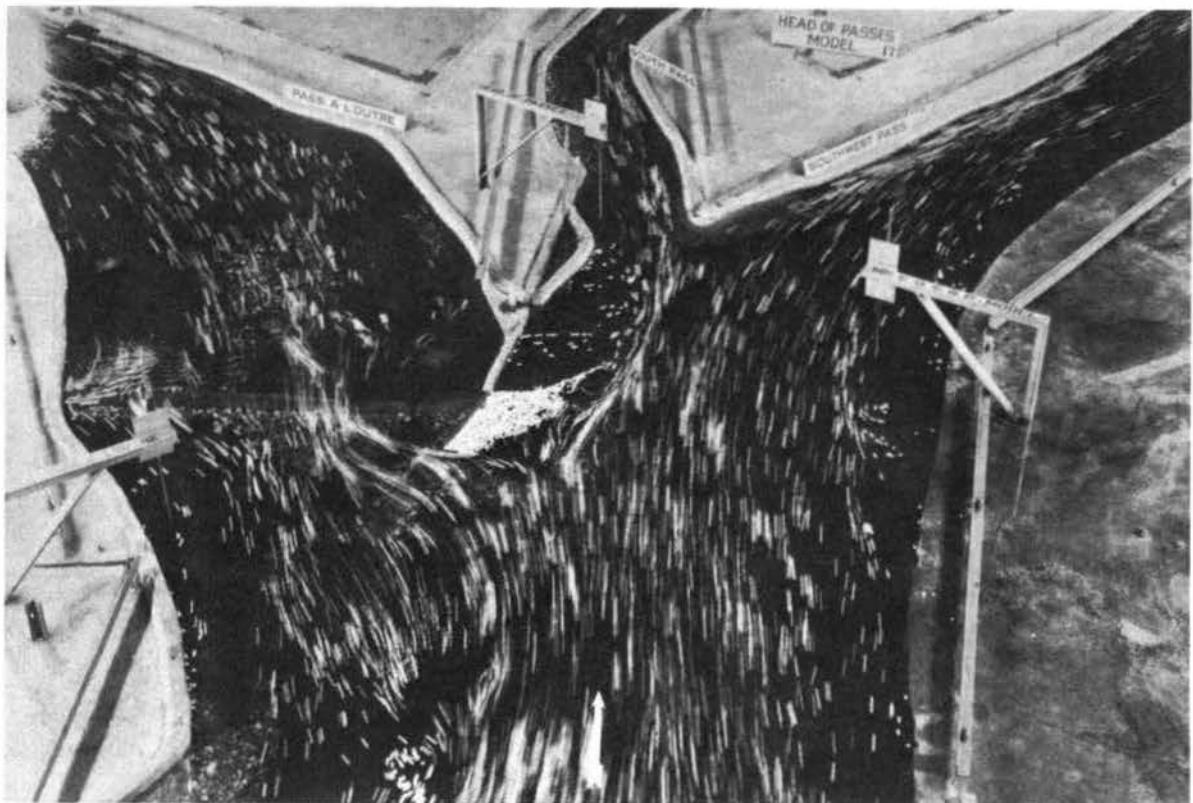
Photograph A2. Base test; test 3<sup>4</sup>. Downstream view showing current alignment into the three main passes during the 20-ft stage. Note eddy formed behind the East Headland



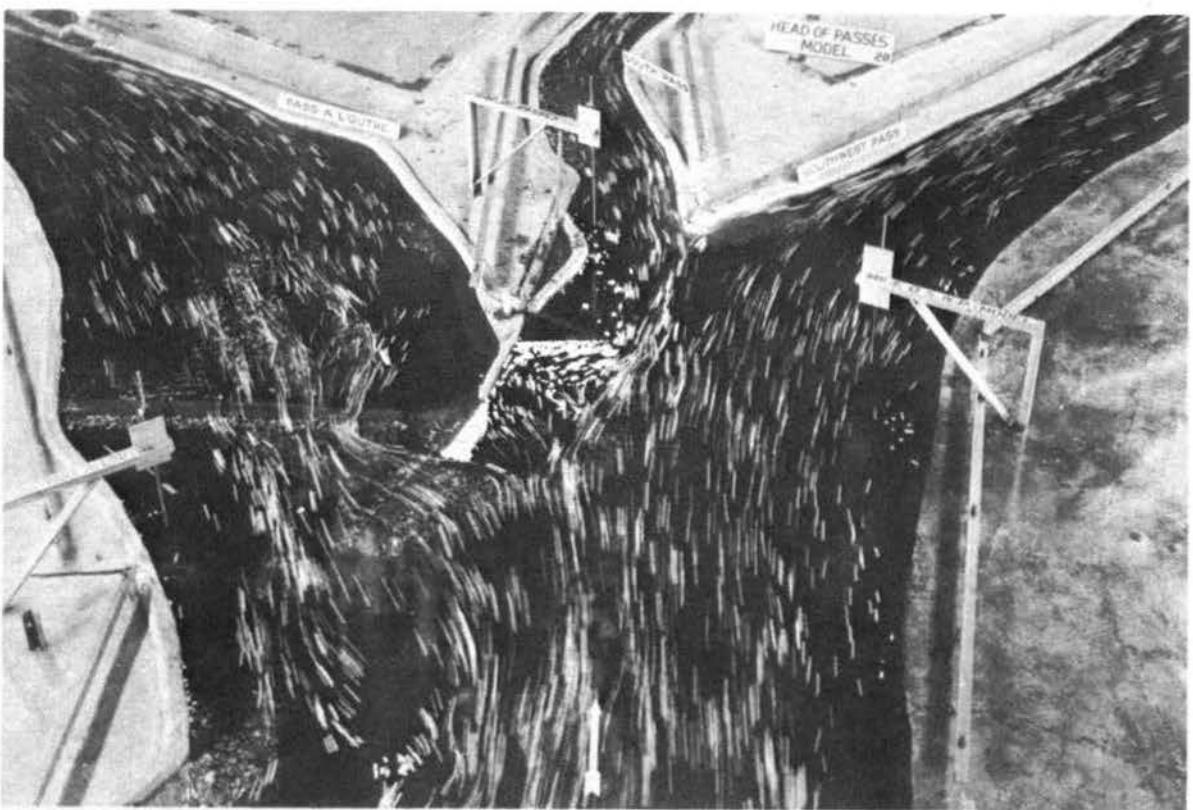
Photograph A3. Plan V; test 35; 17-ft stage. The right-bank dikes produced sufficient contraction, thus enabling Southwest Pass to maintain a navigable channel



Photograph A4. Plan V; test 35; 20-ft stage. The right-bank dikes were not endangered by the 20-ft flood stage

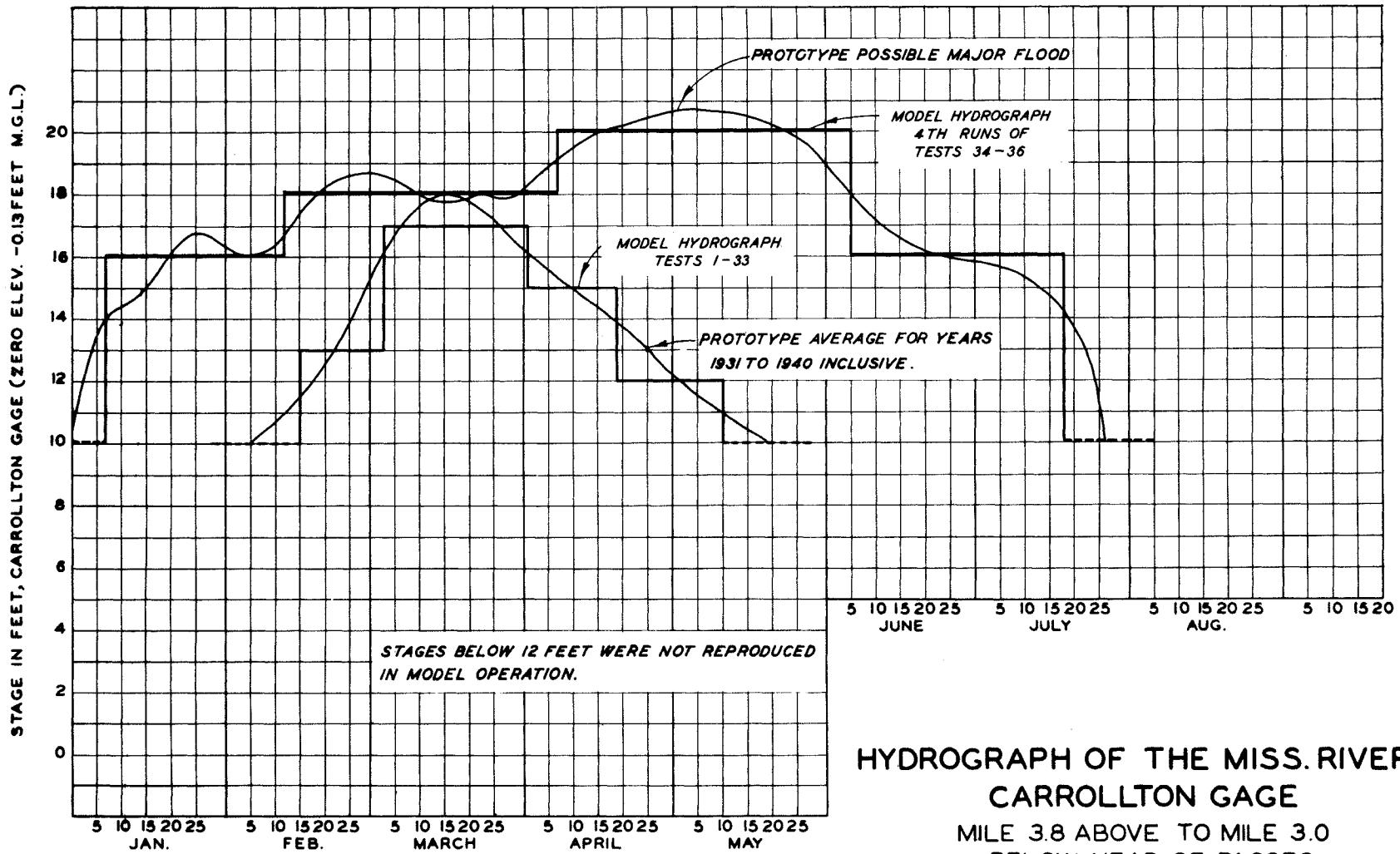


Photograph A5. Plan R-1; test 36; 17-ft stage. A large subsurface eddy was formed between the Pas a Loutre submerged deflecting dike and submerged sill by the extension of the East Headland



Photograph A6. Plan R-1; test 36; 20-ft stage. The upstream dike on the East Headland extension was endangered by the 20-ft flood stage

## PLATES



**HYDROGRAPH OF THE MISS. RIVER  
CARROLLTON GAGE  
MILE 3.8 ABOVE TO MILE 3.0  
BELOW HEAD OF PASSES**

